VOLUME 15, NO. 3
MARCH 1983

THE SHOCK AND VIBRATION DIGEST

A PUBLICATION OF
THE SHOCK AND VIBRATION
INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

OFFICE OF
THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING

THE SHOCK AND VIBRATION DIGEST

Volume 15, No. 3
March 1983

A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 5804, Naval Research Laboratory
Washington, DC 20375
(202) 767-2220

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordon Showalter

Jessica P. Hileman

Elizabeth A. McLaughlin

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman
Vibration Institute
Suite 206, 101 West 55th Street
Clarendon Hills, Illinois 60514
(312) 654-2254

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of $140.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendear year, beginning with the January issue. Back issues are available - Volumes 9 through 14 - for $20.00. Orders may be forwarded at any time to SVIC, Code 5804, Naval Research Laboratory, Washington, DC. 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P-35.

SVIC NOTES

Dr. David Ewins presented some preliminary results of the United States State-of-the-Art Assessment of Mobility Measurements program at the 53rd Shock and Vibration Symposium and at the First International Modal Analysis Conference.

Even though more data remain to be processed, the mobility data on hand show uncertainties that indicate the probable existence of problems in making consistent modal test measurements. These preliminary results raise many important issues, and most of these cannot be properly discussed until more data are processed and the final data banks have been established.

The ability to make consistent mobility measurements is an important issue. The same applies to modal test measurements since both measurements are related. The ability to make consistent measurements implies that different experimenters will make the same measurement with a low degree of uncertainty in the overall results, regardless of the measurement technique that is used.

Until recently, few were concerned about the degree of uncertainty in modal test results. I think this is important for the following reasons. Modal test data are most widely used to validate the mathematical models that are used to generate the analytical results. Modal test data are also used to update or change mathematical models, diagnose the cause(s) of excessive structural vibration, and more recently, to detect structural degradation. The modal test is an important part of the design process, but unless the degree of uncertainty in these test results can be substantially reduced, it will be impossible to use them for any of the foregoing applications with any degree of certainty.

R.H.V.

EDITORS RATTLE SPACE

THE EVOLUTION OF TEST EQUIPMENT

I recently read an article on real time spectrum analyzers in **Electronic Products*** magazine. This excellent survey article pointed out the capabilities of the low-frequency analyzers now on the market. It was interesting that so few companies manufacture analyzers in view of the fact that so many different microprocessors are available. The descriptions of the capabilities of the new four-channel analyzers surprised me, for I had not been aware that so much new capability for data processing and equipment analysis has become available. Then I began to wonder how all this capability will be used.

It has been my experience that very few engineers know how to effectively use even a two-channel analyzer. I have seen very few papers at meetings in which solutions to design or diagnostic problems utilized a two-channel analyzer.

The advent of the four-channel analyzer would seem to indicate that test engineers and experimentalists will soon achieve a position close to finite element analysts. That is, they will have computing capabilities for analysis that far exceed the known fundamental physical knowledge of behavior of dynamic systems. They will be able to provide abstract analyses of systems based on input data and physical understanding that is at best questionable.

I maintain that fundamental information about the behavior of dynamic systems -- particularly damping phenomena -- must be obtained before the electronic tools of today -- even two-channel analyzers -- will be fully effective. I suggest that more research effort should be directed toward understanding the behavior of dynamic systems rather than toward developing tools and procedures based on questionable foundations.

R.L.E.

**Yates, W., "Update! Low Frequency, Real Time FFT Spectrum Analyzers," Electronic Products, 25 (1), Feb 7, 1983.*

FINITE DIFFERENCE METHODS IN VIBRATION ANALYSIS

R. Ali*

Abstract. ***Literature concerned with the application of the finite difference technique to the analysis of natural vibration of engineering components is reviewed. The review covers the period from 1978 to 1982 and concentrates on the analysis of beams, plates, and shells. A brief introduction to the finite difference technique is included.***

Analysis of many vibration problems involves solution of sets of ordinary or partial differential equations. Direct solution of these equations can be achieved in only a few cases; generally numerical techniques must be used. The two most well known numerical techniques are the finite element method and the finite difference method. Both of these methods in conjunction with the digital computer have proved to be powerful techniques for the design and analysis of engineering structures. The finite difference method is particularly suitable for the analysis of vibration characteristics of such structural elements as beams, plates, plates with cutouts, and stiffened plates.

This review is confined to a discussion of the finite difference method and its application to the analysis of structural components. Use of this method to solve a set of differential equations requires that the derivatives of a function be expressed by the appropriate difference expression at finite intervals. The result is a difference equation expressing the differential equation for every node into which the system has been subdivided, thus yielding a set of simultaneous equations. After the appropriate and relevant boundary conditions have been satisfied, this set of equations is solved numerically to yield the desired parameters.

FINITE DIFFERENCE FORMULATION

Consider a function $y = f(x)$ and assume a nodal interval h. The various difference expressions for a node r can be expressed as follows:

$$\left(\frac{\Delta y}{\Delta x}\right)_r = \frac{y_{r+1} - y_{r-1}}{2h}$$

$$\Delta y_r = y_{r+1} - y_{r-1}$$

The quantity Δy_r is the first difference. Similarly the higher order differences are:

$$\begin{aligned} \Delta^2 y_r &= y_{r+1} - 2y_r + y_{r-1} \\ \Delta^3 y_r &= y_{r+2} - 2y_{r+1} + 2y_{r-1} - y_{r-2} \\ \Delta^4 y_4 &= y_{r+2} - 4y_{r+1} - 6y_r - 4y_{r-1} + y_{r-2} \end{aligned} \tag{1}$$

These are the difference expressions for a one-dimensional field. Note that, in this development, nodes located symmetrically with respect to the node under consideration are used. The result is central difference expressions. It is possible to develop difference relations using nodes in ascending order. These relations yield forward difference expressions; using nodes in a descending order results in backward difference expressions.

Consider a two-dimensional field; the difference equations must represent functions with more than one variable. In this case the coordinate axes chosen can be cartesian, polar, or skew depending on the problem. For a one-dimensional problem the two-dimensional domain is divided into a mesh or grid. Difference expressions are derived for all the nodes in the grid by developing first the partial difference in one direction and then the difference of the first differences in the other direction.

Consider a function $Z = f(x,y)$. The central difference expressions for the node (i, j) can be expressed as follows.

***Department of Transport Technology, University of Technology, Loughborough, Leicestershire LE11 3TU, UK**

$$\Delta^2 Z = \frac{1}{4hk}\,(Z_{i+1,j+1} - Z_{i+1,j-1} - Z_{i-1,j+1} + Z_{i-1,j-1})$$

and

$$\Delta^4 Z = \frac{1}{h^2k^2}\,(Z_{i+1,j+1} - 2Z_{i+1,j} + Z_{i+1,j-1} - 2Z_{i,j+1} + 4Z_{i,j} - 2Z_{i,j-1} + Z_{i-1,j+1} - 2Z_{i-1,j} + Z_{i-1,j-1}) \qquad (2)$$

where h and k are nodal spacings in x and y directions respectively. Similarly difference expressions for three or higher dimensional space can be established. Development of difference expressions for all the nodes in a grid leads to a set of simultaneous equations that must be solved to obtain the required results.

Demands for increased accuracy in this type of analysis lead to conflicting requirements. A dense mesh improves the stability of the solution and reduces discretization error but leads to uneconomical solution due to the large core requirement and computation time. However, the analysis can be improved by utilizing unequal intervals, in which case development of difference expressions becomes relatively complex. They must be derived by using Taylor expansions or Lagrangian interpolation.

PLATE VIBRATIONS

Finite difference formulation of the equations of motion has been extensively used for the vibration analysis of various forms of plates. Most authors have used the technique in its standard classical form. No significant improvements in the technique itself have been reported recently. Mukhopadhyay [1] used this method for the analysis of isotropic, orthotropic, and variable thickness plates but considered only rectangular plates. He also used this method to modify a lumped mass system to a parabolically distributed mass system, thus producing an accurate and economical analysis. This work has been extended [2] to rectangular plates with elastically restrained edge conditions and different degrees of restraints. A number of tables of coefficients for various edge flexibilities have been prepared.

It has been pointed out [3] that erroneous results can be obtained when vibration characteristics of plates are analyzed using a one-dimensional finite difference formulation; a two-dimensional alternative approach was suggested [3]. Ganesan [4] presented a vibration analysis of rectangular plates subject to linear temperature gradients. He attempted to correlate the natural frequencies of the plate with temperature gradients. The temperature distribution produced a marginal increase in the fundamental frequency.

Kaldas and Dikinson [5] used the finite difference technique to analyze flexural vibrations of welded rectangular plates. The proposed method is applicable to rectangular plates with any boundary conditions and carrying any number of welds parallel to the edges. The effects of welding processes on the vibration characteristics of these plates are discussed. The authors suggest that this approach could also be used to predict dynamic behavior of plates welded into structures or standard structural elements.

Aksu [6, 7] published a numerical method based on variational principles in conjunction with the finite difference technique; he used the method in the vibration analysis of stiffened and cross-stiffened plates. He used unequal nodal intervals and the concept of interlacing grids and nodal subdomains in a novel formulation of the finite difference scheme that uses first and second order Lagrangian polynomials. He applied this method to the analysis of several rectangular plate systems with stiffeners in one or both directions. The author also investigated the effect of in-plane displacements and in-plane inertia on the natural frequencies of eccentrically stiffened plates.

The axisymmetric vibrations of laminated circular plates have been discussed [8]. The effects of bilayer composition, reversal in bilayer hybrids, material interchange in triple layer composites, core thickness, and two and three materials on composite plate characteristics have been examined. The natural frequencies of the plates were sensitive to material anisotropy and plate layup.

Free vibration analysis of circular sector plates has also been investigated [9]. The dynamic behavior of sector plates with radial edges simply supported and various boundary conditions on the circumferential edge was reported. Appropriate shape functions for this class of plate have been laid out. The author noted that agreement between predicted and measured values deteriorates if the sectorial angle exceeds 120°.

CABLES, BEAMS, AND SHELLS

A numerical simulation procedure based on finite difference representation has been proposed [10] for the prediction of the dynamic response of transmission lines subject to turbulent winds. All nonlinear effects were included in the analysis. Both direct explicit and semi implicit-explicit finite difference formulations were tried. The authors are of the opinion that the latter method is computationally more efficient. Interfacing of the simulation procedure with the numerical procedure was described.

Rega and Luongo [11] reported a natural vibration study of elastic suspended cables with flexible supports. The influence of support flexibility on the dynamic behavior of the cables was examined, as was the importance of the two flexibilities relative to the dynamic behavior of the whole system. It has been established that cable extensibility has a greater influence on the dynamic characteristics of a system than support flexibility. A finite difference algorithm was used for this study; possibilities of adaptation of simpler mathematical models for technical applications were explored. However, the authors warned that the resulting matrices could be unsymmetric unless the nodal interval is small.

Finite difference formulation has been used to determine the dynamic response of elastic-plastic beams subject to dynamic loads [12]. Elastic, perfectly plastic, and a special elastic-viscoplastic strain hardening model were subjected to suddenly applied uniform pressure and concentrated impact loads. Aydin and Aksu [13] used this method in conjunction with variational principles to determine the dynamic characteristics of nonuniform cantilevers and stepped beams and shafts.

A dynamic shell code based on a finite difference formulation was used [14] in an analysis of the dynamic motion of circumferentially oriented through-cracks in steel pipes in the presence of extensive yielding. Crack growth velocities, under dynamic load, for typical pipes were studied and compared with brittle cracks.

Berger [15] presented a numerical solution for the transient vibration of arbitrary shells of revolution surrounded by an acoustic medium. The equations of motion of the acoustic fluid together with the shell fluid boundary equations were expressed in the finite difference form; the results were claimed to be exact to within those approximations usually implicit in such formulation. Only a first few even modes are calculated.

Interlacing grids have been used [16] to develop a general solution for the dynamic behavior of axisymmetric shells of revolution subject to arbitrary dynamic loads. The work was undertaken to determine the influence of shear deformation and rotary inertia on the solution. Three levels of shear stiffnesses were examined; the first eight frequencies of vibration were calculated. It was shown that, for low level of stiffness, the behavior of the shell approached that of a membrane. Sheinman [17] extended this work by including density variation. He used central difference formulation and suggested that this modification allows the method to be used for laminated shells. The method can also be used for rapidly varying and discontinuous loads and is stable for any time interval.

Smith [18] used a combination of central and higher order finite differences to develop equations for the analysis of rotationally symmetric shells subject to time-dependent loadings and boundary conditions. He described a numerical procedure that permits the use of larger meridional and time increments for a given accuracy.

A large deflection elastic-plastic dynamic buckling analysis of axisymmetric spherical caps with initial imperfections has been published [19]. The dynamic buckling loads were functions of geometric parameters in the case of the elastic material and were independent of it in the elastic-plastic range. The effect of material nonlinearity on the dynamic behavior of the caps was also examined. The conclusion was that plastic yielding plays a significant role in reducing the buckling pressure.

MECHANISMS

Sinha and Costello [20] presented a method for determination of the dynamic response of helical springs. Two numerical methods were used for this study, nonlinear characteristics and finite differences. The former method appears to be superior in both accuracy and economy. The authors concluded that the linear theory is reasonably accurate if only axial strains are considered. However, there is considerable error if the linear theory is used for investigations involving rotational strains.

Finite difference formulations in conjunction with the Runga-Kutta-Gill methods have been used [21] to analyze the dynamic behavior of a four bar chain with elastic links and an overhanging coupler. Effects of additional mass at the overhanging end of the coupler on the transverse vibration of the mechanism were described. It is shown that the characteristics of the overhanging coupler greatly influenced the dynamic behavior of the crank level mechanism. A suitable range of overhanging masses was identified for the reduction of strain due to the transverse vibration of the coupler.

Kanango and Patnaik [22] published a study for the reduction of valve gear dynamic loads by means of cam displacement profile modification. The dynamic loads arise as a result of sudden variation of acceleration. The aim of the study was to modify cam profiles through iterative adjustment of displacements so as to minimize acceleration of the follower during its cam imparted motion.

REFERENCES

1. Mukhopadhyay, M., "A Semi-Analytic Solution for Free Vibration of Rectangular Plates," J. Sound Vib., 60 (1), pp 71-85 (Sept 1978).

2. Mukhopadhyay, M., "Free Vibration of Rectangular Plates with Edges Having Different Degrees of Rotational Restraints," J. Sound Vib., 67 (4), pp 459-468 (Dec 1979).

3. Ganesan, N. and Jagadeesan, T.S., "Finite Difference Analysis of the Vibration of Plates with Two Opposite Edges Simply Supported," J. Sound Vib., 60 (1), pp 146-148 (Sept 1978).

4. Ganesan, N., "Vibration of Heated Plates with Two Opposite Edges Simply Supported," J. Sound Vib., 66 (1), pp 99-107 (Sept 1979).

5. Kaldas, M.M. and Dikinson, S.M., "The Flexural Vibration of Welded Rectangular Plates," J. Sound Vib., 75 (2), pp 163-178 (Mar 1981).

6. Aksu, G., "Free Vibration Analysis of Cross Stiffened Rectangular Plates," M.E.T.U. J. Pure Appl. Sci., 9 (2), pp 209-226 (1976).

7. Aksu, G., "Free Vibration Analysis of Stiffened Plates by Including the Effect of Inplate Inertia," J. Appl. Mech., Trans. ASME, 49, pp 206-212 (Mar 1982).

8. Greenberg, J.B. and Stavsky, Y., "Axisymmetric Vibrations of Orthotropic Composite Circular Plates," J. Sound Vib., 61 (4), pp 531-545 (Dec 1978).

9. Mukhopadhyay, M., "A Semi-Analytic Solution for Free Vibration of Annular Sector Plates," J. Sound Vib., 63 (1), pp 87-95 (Mar 1979).

10. Matheson, M.J. and Holmes, J.D., "Simulation of the Dynamic Response of Transmission Lines in Strong Winds," Engrg. Struc., 3 (2), pp 105-110 (Apr 1981).

11. Rega, G. and Luongo, A., "Natural Vibrations of Suspended Cables with Flexible Supports," Computers Struc., 12 (1), pp 65-75 (July 1980).

12. Sperling, A. and Parton, Y., "Numerical Analysis of Large Elastic-Plastic Deformation of Beams Due to Dynamic Loading," Intl. J. Solids Struc., 13 (10), pp 865-876 (1977).

13. Aydin, A.S. and Aksu, G., "Free Vibration Analysis of Nonuniform Beams and Stepped Thickness Beams and Shaft," M.Sc. Thesis, M.E.T.U. Gaziantep, Turkey (1980).

14. Emery, A.F., Kobayashi, A.S., Love, W.J., and Jain, A., "Dynamic Propagation of Circumferential Cracks in Two Pipes with Large Scale Yielding," J. Pressure Vessel Tech., Trans. ASME, 102 (1), pp 28-32 (Feb 1980).

15. Berger, B.S., "Transient Motion of an Elastic Shell of Revolution in an Acoustic Medium," Dept. Mech. Engrg., Univ. Maryland, Rept. No. AD-A042 135/4 GA (May 1977).

16. Tene, Y. and Sheinman, I., "Dynamics of Shells of Revolution under Axisymmetric Load Involving Shear Deformation," Computers Struc., 8 (5), pp 563-568 (May 1978).

17. Sheinman, J. and Zamir, I., "Dynamics of Complex Shells of Revolution with Arbitrary Stiffness and Density Distributions," Intl. J. Numer. Methods Engrg., 15, pp 1713-1723 (Nov 1980).

18. Smith, T.A., "Explicit High Order Finite Difference Analysis of Rotationally Symmetric Shells," AIAA J., 18 (3), pp 309-317 (Mar 1980).

19. Kao, R., "Nonlinear Dynamic Buckling of Spherical Caps with Initial Imperfections," Computers Struc., 12 (1), pp 49-63 (July 1980).

20. Sinha, S.K. and Costello, G.A., "The Numerical Solution of the Dynamic Response of Helical Springs," Intl. J. Numer. Methods Engrg., 12 (6), pp 949-961 (1978).

21. Furuhashi, T., Saito, M., and Morita, N., "Vibration Analysis of Four Bar Linkage with Elastic Links," Bull. JSME, 22 (174), pp 1826-1833 (Dec 1979).

22. Kanango, R.N. and Patnaik, N., "Improving Dynamic Characteristics of a Cam Follower Mechanism through Finite Difference Technique," ASME World Conf. Proc., Theory of Machines Mech. (1979).

LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains articles about dynamic applications of piezoelectric crystals and digital synthesis of response-design spectrum compatible earthquake records for dynamic analyses.

Dr. M. Cengiz Dökmeci of Istanbul Technical University, Istanbul, Turkey, has written a review of current open literature pertaining to the dynamic applications of piezoelectric crystals. Representative theoretical and experimental papers cover waves and vibrations in piezoelectric one-dimensional and two-dimensional structural elements.

Dr. P-T.D. Spanos of University of Texas at Austin, Texas, has written a paper on methods of digital synthesis (simulation) of earthquake records that are compatible with a target (specified) response-design spectrum. The usefulness of a target spectrum-based approach to the design of earthquake resistant structures is addressed.

DYNAMIC APPLICATIONS OF PIEZOELECTRIC CRYSTALS
PART I: FUNDAMENTALS

M.C. Dökmeci*

Abstract. ***This paper presents a review of current open literature pertaining to the dynamic applications of piezoelectric crystals. Representative theoretical and experimental papers cover waves and vibrations in piezoelectric one-dimensional and two-dimensional structural elements. New trends of research are pointed out for future applications of piezoelectric crystals.***

Piezoelectricity, an interdependence of mechanical and electrical properties in certain types of materials, is an exciting new field of applied physics and engineering. This interdisciplinary field has applications in both civil and military industry. The present paper is designed to present an introduction and guide and to stimulate further strides in the field.

INTRODUCTION

Classically, piezoelectricity is electric polarization produced by mechanical strain in certain crystals, the polarization being proportional to the strain and changing sign with it [1]. Piezoelectricity is a reversible, inherently anisotropic, electromechanical phenomenon that was first observed in crystals by the brothers Pierre and Jacques Curie in 1880 [2]. In a piezoelectric crystal, application of mechanical stresses or strains generates electric polarization and hence an electric field; this is referred to as the direct piezoelectric effect. Conversely, application of voltage produces a mechanical distortion of the crystal; this is called the converse, or reciprocal, piezoelectric effect. The converse piezoelectric effect is a thermodynamic consequence of the direct piezoelectric effect, as predicted theoretically by Lippmann [1]. The relations between piezoelectricity and crystals were established by the brothers Curie and then rigorously determined by Voigt [3]. Other treatises [1, 4-7] present the development and applications of piezoelectricity.

Piezoelectricity has generally been observed in anisotropic crystals that lack a center of symmetry [8, 9] and in certain noncrystalline materials as well [10, 11]. An examination of the symmetry group of the 32 crystal classes reveals that, with the exception of one class -- namely, the cubic class 432 -- the 20 classes having no center of symmetry exhibit piezoelectricity; that is, centrosymmetric crystals cannot be piezoelectric. Prominent among the asymmetrical crystals that possess high piezoelectric coupling are quartz (the trigonal class 32), Rochelle salt (the rhombic class 222), and ammonium phosphate (the tetragonal class 42m). Noncrystalline materials and liquid crystals [12], which are viscoelastic fluids with crystal-like behavior, can display piezoelectricity; this phenomenon has been substantiated and experimentally demonstrated [12-17]. Of noncrystalline materials rubber, paraffin, and glass [1]; the piezoelectric textures such as wood [13] and bone [14]; and polymers [15] and ceramics [16-18] possess piezoelectric properties.

Such polymers as polyvinylidenefluoride (PVDF) [19] comprise an important subclass of piezoelectrics called ferroelectrics. Ferroelectrics exhibit strong piezoelectricity; spontaneous polarization as well as induced polarization are caused by an applied electric field [20, 21]. In addition to polymers such piezoelectric ceramics, or piezoceramics, as barium titanate and lead titanate zirconate compositions show ferroelectric behavior. Piezoceramics are made of anisotropic crystalline powders by pressing and sintering; analogous to the magnetizing of magnets, these polycrystalline materials are prepolarized by a strong electric field. Such synthetic piezoelectric materials are reliable and uniform, have high electric and mechanical strength, and are potentially low in

**Istanbul Technical University, P.K. 9, Istanbul, Turkey*

cost. The properties of various piezoelectric materials, including elastic and piezoelectric coefficients, are available [22-28].

Historically, from the discovery of piezoelectricity until the end of World War I, the piezoelectric transducer suggested by Paul Langevin in 1917 was the sole technical application of piezoelectricity [1]. Piezoelectric devices were slowly developed up to the advent of World War II. During and following the war piezoelectric effects were extensively utilized in hydroacoustics, electroacoustics, and electrooptics devices. The past two decades have witnessed a rapid increase in the use of piezoelectric effects, especially in weapons systems and space devices. Synthetic piezoelectric materials allow a wide variety of advantageous geometries, both plane and curved, to be molded and polarized in various directions. These materials have been used as transducers, filters, oscillators, and transmitters. Most of the piezoelectric elements currently used in devices are in the shape of plates, disks, thin films, shells, and laminae, both uncoated and coated. In connection with the design and construction of piezoelectric devices several works are useful [1, 4, 6, 29-32].

With the exception of a few papers dealing with bending and fracture [33-37] all of the investigations concerning piezoelectric crystals have been devoted to dynamic applications. In this article a review of the literature pertaining to the fundamental equations of piezoelectricity and their variational formulations is followed by a review of representative papers involving waves and vibrations in piezoelectric crystals in order to illustrate the present status of research in piezoelectricity. Lastly, need of further research is pointed out for dynamic as well as static applications of piezoelectric crystals.

FUNDAMENTAL EQUATIONS

The motion of an elastic continuum interacting with thermal, electric, or magnetic fields is governed by the fundamental equations of electro-magneto-thermoelasticity [38-42]. The fundamental equations consist of the following: field equations that have been established on the basis of mechanical and electrical balance laws; constitutive relationships that appropriately express the peculiarities of the continuum; and boundary, initial, and jump conditions. The equations can be equivalently and interdependently expressed either in global form through integral expressions, in local or differential form by assuming suitable differentiability conditions, or in variational form by stationarity of pertinent functionals. The global form, though essential and general due to its physical nature, is inappropriate; hence one of the other forms, particularly the variational form, is desirable in most applications. One branch of electro-magneto-thermoelasticity is piezoelectricity; it is a quasi-linear, polarizable but not magnetizable field.

In piezoelectricity, the elastic field is considered dynamic, but the electric field is taken to be static with respect to electromagnetic propagation phenomena. The quasi-static approximation provides an extremely accurate representation for piezoelectricity when electromagnetic waves essentially uncouple from elastic waves, and wavelengths close to those of elastic waves much smaller than electromagnetic waves (the ratio being 10^4 - 10^5) at the same frequency are considered. The approximation was justified by Tiersten [43].

In accordance with the quasi-static approximation, the fundamental equations of piezoelectricity can readily be obtained from those of electro-magneto-thermoelasticity for the case of nonconductors at frequencies far below optical frequencies in which electric charge density, conduction current, and rate of charge of magnetic induction can be set equal to zero. The fundamental equations of piezoelectricity were first presented by Voigt [3] and then others [1, 29, 44-48], who accounted for nonlinear effects that had been experimentally observed [49]. The uniqueness of the fundamental equations of linear piezoelectricity and thermopiezoelectricity have been examined [45, 50]; conditions sufficient for uniqueness were enumerated by means of the classical energy argument. Nowacki [51] has also studied uniqueness, and Lothe and Barnett [52] have commented on the existence of piezoelectric surface waves.

Wave propagation equations. The wave propagation equations of thermopiezoelectricity can be expressed in differential form as

$$c_{ijkl}\frac{\partial^2 u_k}{\partial x_l \partial x_i} + e_{kij}\frac{\partial^2 \phi}{\partial x_k \partial x_i} - \lambda_{ij}\frac{\partial \theta}{\partial x_i} = \rho \frac{\partial^2 u_j}{\partial t^2}$$

$$e_{kij}\frac{\partial^2 u_i}{\partial x_j \partial x_k} - \epsilon_{ij}\frac{\partial^2 \phi}{\partial x_i \partial x_j} + p_i \frac{\partial \theta}{\partial x_i} = 0$$

$$\lambda_{ij}\frac{\partial^2 u_i}{\partial x_j \partial t} - p_i \frac{\partial^2 \phi}{\partial x_i \partial t} + \alpha \frac{\partial \theta}{\partial t} = \Theta_0^{-1} \kappa_{ij}\frac{\partial^2 \theta}{\partial x_i \partial x_j}$$

These equations have been deduced from fundamental linear equations by successive substitution of five field quantities, namely, u_k the mechanical displacement, θ the small temperature change, and ϕ the electric potential.

In the equations Einstein's summation convention is implied for all repeated indices. Also, t denotes time, ρ is mass density, x_k stands for space coordinates, c_{ijkl} are the elastic constants, e_{kij} are the piezoelectric strain constants, λ_{ij} are the thermal stress constants, ϵ_{jk} is the dielectric permittivity, κ_{ij} are the heat conduction coefficients, and p_i are the pyroelectric constants. The material constant α is equal to $\rho C_\nu \Theta_0^{-1}$. C_ν is the specific heat under constant volume and Θ_0 the reference temperature for θ ($\theta \ll \Theta_0$). Of the material constants, c_{ijkl} refer to free constants because they describe stress-strain relations in the absence of electric and thermal fields; the rest of the coefficients refer to clamped constants [9].

The above set of wave propagation equations should be solved for each case of interest under suitable boundary and initial conditions, as well as jump conditions. Further, the wave equations of thermopiezoelectricity reduce to the classical wave equations in the case of vanishing electric and thermal fields.

Variational principles. To reproduce the fundamental equations variational principles have been formulated that allow the establishment of approximate theories of piezoelectricity as well as approximate direct solutions. The variational principles of piezoelectricity have been primarily derived by use of Hamilton's principle, as has been illustrated by Mindlin [53], and also through the principle of virtual work and the method of convolution.

Analogous to Mindlin's first variational principle there have been proposals for variational principles in piezoelectricity, they have been elaborated and unified by Tiersten in his notable monograph [45]. Another elegant variational principle has been constructed that can be used to estimate posteriorly the errors of direct solutions [54]. The variational principles for thermopiezoelectricity have been derived [50, 51, 55, 56]. The variational principles, with the exception of a few [55-57], may generate only some of the fundamental equations of piezoelectricity; the remaining equations are contained as constraints. However, variational principles with no constraints or as few constraints as possible are desirable in most applications, this point has been thoroughly studied [58].

Dökmeci [56] applied Tiersten's method of derivation [58] and proposed a quasi-type, unconstrained variational principle for a thermopiezoelectric region with a surface of discontinuity. He considered the nonlinear constitutive relations as well as all the initial and jump conditions. A variational principle for fracture of piezoelectric continua has been derived [35, 59]. Extension of the theorem of classical elasticity [60] has allowed derivation of a reciprocal theorem for piezoelectricity [61] and for thermopiezoelectricity [51, 62]. A recent boundary element formulation has been made for linear piezoelectric problems [63].

REFERENCES

1. Cady, W.G., Piezoelectricity, Vols 1 and 2, Dover Publications (1964).

2. Curie, P., Oeuvres de Pierre Curie, Gauthier-Villars & Cie (1908).

3. Voigt, W., Lehrbuch der Kristallphysik, Teubner (1910).

4. Mason, W.P., Piezoelectric Crystals and Their Applications to Ultrasonics, D. van Nostrand Co. (1950).

5. Zheludev, I.S., Physics of Crystalline Dielectrics, Vols 1 and 2, Plenum Press (1971).

6. Bergmann, L., Der Ultraschall und seine Anwendung in Wissenschaft und Technic, Hirzel (1954); Eng. Tr., Ultrasonics and Their Scientific and Technical Applications, John Wiley and Sons (1968).

7. Mason, W.P., "Piezoelectricity, Its History and Applications," J. Acoust. Soc. Amer., 70 (6), pp 1561-1566 (1981).

8. Nye, J.F., Physical Properties of Crystals, The Clarendon Press (1957).

9. Venkataraman, G., Feldkamp, L.A., and Sahni, V.C., Dynamics of Perfect Crystals, The M.I.T. Press (1975).

10. Shubnikov, A.V., Zheludev, I.S., Konstantinova, V.P., and Silvestrova, I.M., Issledovanie Piezoelektritcheskikh Textur, Izd-vo AN SSSR (1955); French Tr., Etude des Textures Piezoelectriques, Dunod (1958).

11. Jaffe, B., Cook, W.R., and Jaffe, H., Piezoelectric Ceramics, Academic Press (1971).

12. Kagawa, Y. and Hatakeyama, T., "Piezoelectric Effect in Liquid Crystals," J. Sound Vib., 53 (4), pp 585-593 (1977).

13. Bazhenov, V.A., Piezoelectric Properties of Wood, Consultants Bureau (1961).

14. Fukada, E., "Mechanical Deformation and Electrical Polarizstion in Biological Substances," Biorheology, 5 (1), pp 199-208 (1968).

15. Fukada, E., "Piezoelectricity in Polymers and Biological Substances," Ultrasonics, 6 (4), pp 229-234 (1968).

16. Déri, M., Ferroelectric Ceramics, Maclaren (1966).

17. Van Randeraat, J. (editor), Piezoelectric Ceramics, Philips Gloeilampenfabrienken (1968).

18. Berlincourt, D., "Piezoelectric Ceramics: Characteristics and Applications," J. Acoust. Soc. Amer., 70 (6), pp 1586-1595 (1981).

19. Sessler, G.M., "Piezoelectricity in Polyvinylidenefluoride," J. Acoust. Soc. Amer., 70 (6), pp 1596-1608 (1981).

20. Jona, F. and Shirane, G., Ferroelectric Crystals, Pergamon Press (1962).

21. Grindlay, J., An Introduction to the Phenomenological Theory of Ferroelectricity, Pergamon Press (1970).

22. Forsbergh Jr., P.W., "Piezoelectricity, Electrostriction and Ferroelectricity," Encyclopedia of Physics, Vol XVII: Dielectrics, pp 264-392, Springer-Verlag (1956).

23. Berlincourt, D.A., Curran, D.R., and Jaffe, H., Piezoelectric and Piezomagnetic Materials and Their Function in Transducers," Physical Acoustics, Vol 1 - Part 1, pp 169-270, Academic Press (1964).

24. Bechmann, R., Hearmon, R.F.S., and Kurtz, S.K., Elastic, Piezoelectric, Piezooptic and Electrooptic Constants of Crystals, Numerical Data and Functional Relationships in Science and Technology, Vol 1, Springer-Verlag (1966).

25. "IRE Standards on Piezoelectric Crystals, 1949," Proc. IRE, 37, pp 1378-1395 (1949).

26. "IRE Standards on Piezoelectric Crystals -- The Piezoelectric Vibrator: Definitions and Meth-

ods of Measurement, 1957," Proc. IRE, 45, pp 353-358 (1957).

27. "IRE Standards on Piezoelectric Crystals: Determination of the Elastic, Piezoelectric, and Dielectric Constants -- The Electromechanical Coupling Factor, 1958," Proc. IRE, 46, pp 764-778 (1958).

28. "IRE Standards on Piezoelectric Crystals: Measurements of Piezoelectric Ceramics, 1961," Proc. IRE, 49, pp 1161-1169 (1961).

29. Mason, W.P., Crystal Physics of Interaction Processes, Academic Press (1966).

30. Holland, R. and Eer Nisse, E.P., Design of Resonant Piezoelectric Devices, Res. Monog. No. 56, The M.I.T. Press (1969).

31. Nagy, N.F.L. and Joyce, G.C., "Solid State Control Elements Operating in Piezoelectric Principles," Physical Acoustics, Vol IX, pp 129-165, Academic Press (1972).

32. Domarkas, V.I. and Kazys, R.J., Kontrolesmatavimo Pjezoelektriniai Keitikliai (Russian), (Piezoelectric Transducers for Measuring Devices), Mintis (1975).

33. Keuning, D.H., "Approximate Equations for the Flexure of Thin, Incomplete, Piezoelectric Bimorphs," J. Engrg. Math., 5 (4), pp 307-319 (1971).

34. Mindlin, R.D., "Torsion and Flexure of Piezoelectric Crystal Bars," Application of Elastic Waves in Electrical Devices, Non-Destructive Testing, and Seismology, pp 83-99, NSF Engrg. Mech. Sec., Solid Mech. Prog. (1976).

35. Parton, V.Z., "Fracture Mechanics of Piezoelectric Materials," Acta Astronautica, 3 (9/10), pp 671-683 (1976).

36. Kosmodamianskii, A.S., Kravchenko, A.P., and Lozhkin, V.N., "Electroelastic State of a Piezoelectric Half Plane with Elliptical Core," Sov. Appl. Mech., 14 (10), pp 1073-1078 (1978); Prikl. Mekh., 14 (10), pp 75-81.

37. Ricketts, D., "Model for a Piezoelectric Polymer Flexural Plate Hydrophone," J. Acoust. Soc. Amer., 70 (4), pp 929-935 (1981).

38. Landau, L.D. and Lifshitz, E.M., Electrodynamics of Continuous Media, Addison-Wesley (1960).

39. Truesdell, C. and Toupin, R., "Classical Field Theories," Encyclopedia of Physics, Vol III/1: Principles of Classical Mechanics and Field Theory, pp 226-793, Springer-Verlag (1960).

40. Tamm, I.E., Principles of the Theory of Electricity, Fizmatgiz (1965).

41. Stratton, J.A., Electromagnetic Theory, McGraw-Hill (1941).

42. Parkus, H., (editor), Electromagnetic Interactions in Solids, Springer-Verlag (1979).

43. Tiersten, H.F., "The Radiation and Confinement of Electromagnetic Energy Accompanying the Oscillations of Piezoelectric Crystal Plates," Recent Advances in Engineering Science, Vol V, Part I, pp 63-90, Gordon and Breach (1970).

44. Mindlin, R.D., "On the Equations of Motion of Piezoelectric Crystals," Problems of Continuum Mechanics, pp 282-290, SIAM (1961).

45. Tiersten, H.F., Linear Piezoelectric Plate Vibrations, Plenum Press (1969).

46. Nowacki, W., "Foundations of Linear Piezoelectricity," Electromagnetic Interactions in Solids, pp 105-157, Springer-Verlag (1979).

47. Thurston, R.N., "Waves in Solids," Encyclopedia of Physics, Vol VIa/4, Mechanics of Solids, pp 109-308, Springer-Verlag (1974).

48. Nelson, D.F., "Theory of Nonlinear Electoacoustics of Dielectric, Piezoelectric, and Pyroelectric Crystals," J. Acoust. Soc. Amer., 63 (6), pp 1738-1748 (1978).

49. Gagnepain, J.J. and Besson, R., "Nonlinear Effects in Piezoelectric Quartz Crystals,"

Physical Acoustics, Vol X1, pp 245-288, Academic Press (1975).

50. Mindlin, R.D., "Equations of High Frequency Vibrations of Thermopiezoelectric Crystal Plates," Intl. J. Solids Struc., 10, pp 625-637 (1974).

51. Nowacki, W., "Some General Theorems of Thermopiezoelectricity," J. Thermal Stresses, 1 (2), pp 171-182 (1978).

52. Lothe, J. and Barnett, D.M., "On the Existence of Surface Wave Solutions in Piezoelectric Crystals, An Example of Non-existence," Wave Motion, 1 (1), pp 107-112 (1979).

53. Mindlin, R.D., Theory of Beams and Plates, Lecture notes at Columbia University (1956).

54. Gubenkov, A.N., Kirichenko, V.F., Kulikov, E.L., and Pavlov, S.P., "A Variational Principle for Problems in the Analysis of Piezoelectric Devices with Acoustoelectric Coupling," Sov. Phys. Acoust., 24 (2), pp 111-114 (1978); Akust. Zh., 24, pp 195-202.

55. Dökmeci, M.C., "Theory of Vibrations of Coated, Thermopiezoelectric Laminae," J. Math. Phys., 19 (1), pp 109-126 (1978).

56. Dökmeci, M.C., "Recent Advances: Theory of Vibrations of Piezoelectric Crystals," Intl. J. Engrg. Sci., 18 (3), pp 431-448 (1980).

57. Dökmeci, M.C., "Variational Principles for Linear Piezoelectricity," L. Al Nuovo Cimento, 7 (11), pp 449-454 (1973).

58. Tiersten, H.F., "Natural Boundary and Initial Conditions from a Modification of Hamilton's Principle," J. Math. Phys., 9 (9), pp 1445-1451 (1968).

59. Kudriavtsev, B.A., Parton, V.Z., and Rakitin, V.I., "Fracture Mechanics of Piezoelectric Materials. Axisymmetric Crack on the Boundary with a Conductor," Sov. Appl. Math. Mech., 39 (2), pp 328-338 (1975); PMM, 39, pp 352-362.

60. Carlson, D.E., "Linear Thermoelasticity," Encyclopedia of Physics, Vol VIa/2, Mechanics of Solids, pp 297-345, Springer-Verlag (1972).

61. Müller, L., "The Reciprocal Theorem for Piezoelectrics as Interpreted by R.D. Mindlin," Bull. Acad. Polonaise Sci., Ser. Sci. Techn., 28 (1/2), pp 27-32 (1980).

62. Brzezinski, A., "Reciprocal Theorem for Piezoelectric Thermoelasticity," Bull. Acad. Polonaise Sci., Ser. Sci. Techn., 26 (2), pp 143-150 (1978).

63. Tanaka, K. and Tanaka, M., "A Boundary Element Formulation in Linear Piezoelectric Problems," Z. angew Math. Phys., 31 (5), pp 568-580 (1980).

64. Alekseev, B.N., Dianov, D.B., and Karuzo, S.P., "Tapered Piezoelectric Bar Transducer with Transverse Polarization of the Piezoceramic," Sov. Phys. Acoust., 23 (1), pp 1-4; Akust. Zh., 23, pp 1-8 (1977).

65. Alekseev, B.N., Dianov, B.N., and Karuzo, S.P., "Composite Tapered Piezoceramic Bar Transducer," Sov. Phys. Acoust., 24 (2), pp 98-101; Akust. Zh., 24, pp 168-173 (1978).

66. Bondarenko, A.A., Kutsenko, G.V., and Ulitko, A.F., "Amplitudes and Phases of Longitudinal Vibrations of Piezoceramic Rods with Account of Variable Mechanical Quality Factor," Sov. Appl. Mech., 16 (11), pp 1001-1004 (1981), Prikl. Mekh., 16 (11), pp 84-88.

67. Busher, M.K. and Syrkin, L.N., "Application of the Reissner Mixed Variational Principle from the Theory of Elasticity for the Calculation of Inhomogeneous Piezoceramic Bar Transducers," Sov. Phys. Acoust., 24 (5), pp 374-378 (1979); Akust. Zh., 24, pp 664-672.

68. Cherpak, V.A., "Dynamic Lumped Parameters of Composite Piezoelectric Transducers," Sov. Phys. Acoust., 23 (3), pp 246-250 (1977); Akust. Zh., 23, pp 443-449.

69. Das, A. and Ray, A., "Forced Transient Motion of a Piezoelectric Bar and Its Voltage Re-

sponse," Indian J. Tech., 18, pp 349-353 (1980).

70. Zharii, O.Yu., "Discharge of a Piezoceramic Rod in Shock Loading," Sov. Appl. Mech., 17 (3), pp 284-288 (1981); Prikl. Mekh., 17 (3), pp 98-103.

71. Dökmeci, M.C., "A Theory of High Frequency Vibrations of Piezoelectric Crystal Bars," Intl. J. Solids Struc., 10 (4), pp 401-409 (1974).

72. Mindlin, R.D., "High Frequency Vibrations of Piezoelectric Crystal Plates," Intl. J. Solids Struc., 8, pp 895-906 (1972).

73. Lee, P.C.Y. and Haines, D.W., "Piezoelectric Crystals and Electro-Elasticity," R.D. Mindlin and Applied Mechanics, pp 227-253, Pergamon Press (1974).

74. Sinha, B.K. and Stevens, D.S., "Thickness-shear Vibrations of a Beveled AT-cut Quartz Plate," J. Acoust. Soc. Amer., 66 (1), pp 192-196 (1979).

75. Kasatkin, B.A. and Lebedev, V.G., "Spectrum of Natural Frequencies of a Loaded Piezoelectric Plate with a Transition Layer," Sov. Phys. Acoust., 25 (3), pp 224-227 (1979); Akust. Zh., 25, pp 395-400.

76. Aronov, B.S. and Nikitin, L.B., "Calculation of the Flexural Modes of Piezoceramic Plates," Sov. Phys. Acoust., 27 (5), pp 382-387 (1982); Akust. Zh., 27, pp 687-696.

77. Lozhkin, V.N., "Low-frequency Vibrations of Piezocrystalline Plates," Sov. Appl. Mech., 17, pp 673-677 (1982); Prikl. Mekh., 17, pp 89-93.

78. Schwarz, R., "Dreidimensionales Modell einer quaderförmigen Piezokeramik für longitudinale Wellenausbreitung," Acustica, 47 (4), pp 275-282 (1981).

79. Shnitser, P.I., "Analysis of Oscillations in an Open Acoustic Resonator with Reflective Piezoelectric Transducers," Sov. Phys. Acoust., 26 (3), pp 244-247 (1980); Akust. Zh., 26, pp 446-452.

80. Gitis, M.B. and Shenker, A.A., "Pulsed Operation of a Flat Piezoelectric Transducer," Sov. Phys. Acoust., 27 (6), pp 469-472 (1982); Akust. Zh., 27, pp 848-854.

81. Kagawa, Y. and Yamabuchi, T., "Finite Element Simulation of a Composite Piezoelectric Ultrasonic Transcucer," IEEE SU-26 (2), pp 81-88 (1979).

82. Das, A. and Ray, A., "Transient Stresses and Voltage Developed in a Spinning Disc of Radially Inhomogeneous Piezoelectric Material," J. Sound Vib., 67 (1), pp 75-87 (1979).

83. Vovkodav, I.F., Karlash, V.L., and Ulitko, A.F., "Axisymmetric Vibrations of Thin Piezoceramic Disks with Split Electrodes," Sov. Appl. Mech., 15 (2), pp 148-152 (1979); Prikl. Mekh., 15, pp 77-82.

84. Aronov, B.S., "Calculation of the Radial Modes of Piezoceramic Disks with Axisymmetrical Electrodes," Sov. Appl. Mech., 16 (11), pp 986-992 (1981); Prikl. Mekh., 16, pp 65-72.

85. Kirichok, I.F., "Heat Release Associated with the Electroelastic Modes of Piezoelectric Ceramic Disks," Sov. Appl. Mech., 16 (10), pp 902-905 (1981); Prikl. Mekh., 16, pp 82-86.

86. Adelman, N.T. and Stavsky, Y., "Flexural-extensional Behavior of Composite Piezoelectric Circular Plates," J. Acoust. Soc. Amer., 67 (3), pp 819-822 (1980).

87. Schwarzenbach, H.U., Lechner, H., Steinle, B., Baltes, H.P. and Schwendmann, P., "Calculation of Vibrations of Thick Piezoceramic Disk Resonators," Appl. Phys. Lett., 38 (11), pp 854-855 (1981).

88. Barilov, E.S., Vassergiser, M.E., and Dorosh, A.G., "Calculation of Equivalent-Circuit Parameters for a Radially Polarized Piezoceramic Sphere," Sov. Phys. Acoust., 25 (3), pp 199-202 (1979); Akust. Zh., 25, pp 352-357.

89. Borisyuk, A.I. and Kirichok, I.F., "Steady-State Radial Vibrations of Piezoceramic Spheres in Compressible Fluid," Sov. Appl. Mech.,

15 (10), pp 936-940 (1980); Prikl. Mekh., 15 (10), pp 45-49.

90. Kirichok, I.F., "Numerical Solution of Problems of the Electroelastic Oscillation of a Cylinder and a Sphere," Sov. Appl. Mech., 16 (2), pp 121-125 (1980); Prikl. Mekh., 16 (2), pp 45-50.

91. Gololobov, V.I., "Numerical Analysis of Piezoelectric Ceramic Shells of Revolution," Sov. Appl. Mech., 17 (4), pp 339-343 (1981); Prikl. Mekh., 17 (4), pp 38-42.

92. Burt, J.A., "The Electroacoustic Sensitivity of Radially Polarized Ceramic Cylinders as a Function of Frequency," J. Acoust. Soc. Amer., 64 (6), pp 1640-1644 (1978).

93. Busher, M.K., "Dynamic Equations for a Piezoceramic Radiating Transducer Having an Inhomogeneous Structure," Sov. Phys. Acoust., 24 (6), pp 476-479 (1979); Akust. Zh., 24, pp 835-843.

94. Abdulgalimov, A.M., "Vibration of Cylindrical Piezocoverters of Finite Size," Moscow Univ. Mech. Bull., 36 (2), pp 38-42 (1981); Vestnik Moskovskogo Univ. Mekh., 36 (2), pp 71-76.

95. Kasatkin, B.A., "Generalized Orthogonality Relations for the Normal Modes of a Piezoelectric Waveguide and Their Application in the Theory of Resonators," Sov. Phys. Acoust., 27 (4), pp 290-292 (1982); Akust. Zh., 27, pp 520-525.

96. Sarma, K.V., "Torsional Wave Motion of a Finite Inhomogeneous Piezoelectric Cylindrical Shell," Intl. J. Engrg. Sci., 18, pp 449-454 (1980).

97. Srinivasamoorthy, V.R. and Anandam, C., "Torsional Wave Propagation in an Infinite Piezoelectric Cylinder (622) Crystal Class," J. Acoust. Soc. Amer., 67 (6), pp 2034-2035 (1980).

98. Paul, H.S. and Raju, D.P., "Asymptotic Analysis of the Torsional Modes of Wave Propagation in a Piezoelectric Solid Circular Cylinder of (622) Class," Intl. J. Engrg. Sci., 19, pp 1069-1076 (1981).

99. Dianov, D.B., Zadirienko, I.M., and Kuz'menko, A.G., "Acoustical Characteristics of a Baffled Cylindrical Piezoelectric Transducer Radiating through a Liquid Layer," Sov. Phys. Acoust., 27 (3), pp 197-199 (1981); Akust. Zh., 27, pp 358-362.

100. Lakes, R., "Shape-Dependent Damping in Piezoelectric Solids," IEEE SU-27 (4), pp 208-213 (1980).

101. Martin, G.E., "Dielectric, Piezoelectric, and Elastic Losses in Longitudinally Polarized Segmented Ceramic Tubes," U.S. Navy J. Underwater Acoust., 15, pp 329-332 (1965).

102. Sittig, E.K., "Design and Technology of Piezoelectric Transducers for Frequencies above 100 MHz," Physical Acoustics, Vol. IX, pp 221-275, Academic Press (1972).

103. Kasatkin, B.A., "Generalized Orthogonality of Normal Modes of Layered Piezoelectric Transducers," Sov. Phys. Acoust., 25 (5), pp 402-405 (1980); Akust., Zh., 25, pp 710-716.

104. Kasatkin, B.A., "Pulse and Transient Responses of a Water-Loaded Layered Piezoelectric Transducer," Sov. Phys. Acoust., 27 (1), pp 85-86 (1981); Akust. Zh., 27, pp 153-155.

105. Mindlin, R.D., An Introduction to the Mathematical Theory of Vibrations of Elastic Plates, U.S. Army Signal Corps Engrg. Lab., Fort Monmouth (1955).

106. Bugdayci, N. and Bogy, D.B., "A Two-Dimensional Theory for Piezoelectric Layers Used in Electro-mechanical Transducers - I: Derivation and II: Applications," Intl. J. Solids Struc., 17 (12), pp 1159-1178 and 1179-1202 (1981).

107. Bugdayci, N. and Bogy, D.B., "A Two-Dimensional Theory for Piezoelectric Layers Used in Electro-mechanical Transducers - II: Applications," Intl. J. Solids Struc., 17 (12), pp 1179-1202 (1981).

108. Boucher, D., Lagier, M., and Maerfeld, C., "Computation of the Vibrational Modes for Piezoelectric Array Transducers Using a Mixed Finite Element-Perturbation Method," IEEE SU-28 (5), pp 318-330 (1981).

109. Stepanishen, P.R., "Pulsed Transmit/Receive Response of Ultrasonic Piezoelectric Transducers," J. Acoust. Soc. Amer., 69 (6), pp 1815-1827 (1981).

110. Wellekens, C.J., "Vibrations of Backed Piezoceramic Disk-Transducers with Annular Electrodes and Matching Layers - Part I," IEEE SU-29 (1), pp 26-37 (1982).

111. Wellekens, C.J., "Vibrations of Backed Piezoceramic Disk-Transducers with Annular Electrodes and Matching Layers - Part II," IEEE SU-29 (1), pp 37-42 (1982).

112. White, R.M., "Surface Elastic Waves," Proc. IEEE, 58, pp 1238-1276 (1970).

113. Viktorov, I.A., "Types of Acoustic Surface Waves in Solids (Review)," Sov. Phys. Acoust., 25 (1), pp 1-9 (1979); Akust. Zh., 25, pp 1-17.

114. Auld, B.A., Acoustic Fields and Waves in Solids, Vols. 1 and 2, John Wiley and Sons (1973).

115. Dieulesaint, E. and Royer, D., Elastic Waves in Solids, John Wiley and Sons (1980).

116. Farnell, G.W., "Types and Properties of Surface Waves," Acoustic Surface Waves, pp 13-60, Springer-Verlag (1978).

117. Gerard, H.M., "Principles of Surface Wave Filter Design," Acoustic Surface Waves, pp 61-96, Springer-Verlag (1978).

118. Ash, E.A., "Fundamentals of Signal processing Devices," Acoustic Surface Waves, pp 97-185, Springer-Verlag (1978).

119. Oliner, A.A., "Waveguides for Surface Waves," Acoustic Surface Waves, pp 187-223, Springer-Verlag (1978).

120. Slobodnik, Jr., A.J., "Materials and Their Influence on Performance," Acoustic Surface Waves, pp 225-303, Springer-Verlag (1978).

121. Smith, H.I., "Fabrication Techniques for Surface Wave Devices," Acoustic Surface Waves, pp 305-324, Springer-Verlag (1978).

122. Sinha, B.K. and Tiersten, H.F., "On the Influence of a Flexural Biasing State on the Velocity of Piezoelectric Surface Waves," Wave Motion, 1 (1), pp 37-51 (1979).

123. Datta, S., Theory of Guided Acoustic Waves in Piezoelectric Solids, Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign (1979).

124. Shimizu, Y. and Terazaki, A., "Attenuation and Velocity of Surface Waves on a Piezoelectric Substrate Coated with Admittance Films," J. Acoust. Soc. Amer., 66 (3), pp 806-810 (1979).

125. Nalamwar, A.L. and Epstein, M., "Surface Acoustic Waves in Strained Media," J. Appl. Phys., 47 (1), pp 43-48 (1976).

126. Tsutsumi, M. and Kumagai, N., "Behavior of Bleustein-Gulyaev Waves in a Periodically Corrugated Piezoelectric Crystal," IEEE MTT-28 (6), pp 627-632 (1980).

127. Pyatakov, P.A., "Structure of the Wave Field Associated with Excitation of a Gulyaev-Bleustein Wave," Sov. Phys. Acoust., 24 (3), pp 218-221 (1978); Akust. Zh., 24, pp 394-400.

128. Morocha, A.K., Ovsyannikova, O.B., and Shermergor, T.D., "Amplification of Stonely Waves at an Interface between a Piezoelectric Semiconductor and a Dielectric Crystal," Sov. Phys. Acoust., 24 (3), pp 212-214 (1978); Akust. Zh., 24, pp 383-387.

129. Viktorov, I.A. and Pyatakov, P.A., "Acoustoelectric Interactions on Cylindrical Surfaces of Piezoelectric Semiconductors," Sov. Phys. Acoust., 25 (2), pp 159-161 (1979); Akust. Zh., 25, pp 290-293.

130. Viktorov, I.A. and Pyatakov, P.A., "Influence of the Piezoelectric Effect on the Properties of Transverse Surface Waves on Cylindrical Surfaces of Crystals," Sov. Phys. Acoust., 24 (1), pp 28-30 (1978); Akust. Zh., 24, pp 53-58.

131. Gulyaev, Yu.V. and Plesskii, V.P., "Acoustic Gap Waves in Piezoelectric Materials," Sov. Phys. Acoust., 23 (5), pp 410-413 (1978); Akust. Zh., 23, pp 716-723.

132. Mozhaev, V.G., "Shear-Wave Convolution in a Layered Piezoelectric-Semiconductor Structure," Sov. Phys. Acoust., 27 (2), pp 156-159 (1981); Akust. Zh., 27 pp 285-290.

133. Horvat, P. and Auld, B.A., "Attenuation des Ondes de Cisaillement Horizontal et des Ondes de Lamb dans les Films Piézoélectriques de Poly (fluorure de vinylidène)," C.R. Acad. Sci., 290, Série B, pp 333-336 (1980).

134. Noorbehesht, B. and Wade, G., "Reflection and Transmission of Plane Elastic Waves at the Boundary between Piezoelectric Materials and Water," J. Acoust. Soc. Amer., 67 (6), pp 1947-1953 (1980).

135. Burlak, G.N., Kotsarenko, N., Ya., and Pustyl'nik, T.N., "Parametric Excitation of Acoustic Waves in Bounded Piezoelectrics," Sov. Phys. Acoust., 22 (6), pp 1059-1061 (1980); Akust. Zh., 22, pp 1825-1828.

136. Burlak, G.N. and Kotsarenko, N.Ya., "Generation of Acoustic Waves in Crystals with the Nonlinear Piezoelectric Effect in the Presence of Reflection," Sov. Phys. Acoust., 27 (1), pp 81-83 (1981); Akust. Zh., 27, pp 148-150.

137. Taylor, D.B. and Crampin, S., "Surface Waves in Anisotropic Media: Propagation in a Homogeneous Piezoelectric Halfspace," Proc. Royal Soc. London, Ser. A 364, pp 161-179 (1978).

138. Mozhaev, V.G. and Solodov, I. Yu, "Second-Harmonic Generation of Acoustic Surface Waves in a Layered Piezoelectric Insulator-Semiconductor Structure," Sov. Phys. Acoust., 26 (3), pp 236-240 (1980); Akust. Zh., 26, pp 433-439.

139. Tiersten, H.F., Sinha, B.K., and Meeker, T.R., "Intrinsic Stress in Thin Films Deposited on Anisotropic Substrates and Its Influence on the Natural Frequencies of Piezoelectric Resonators," J. Appl. Phys., 52 (9), pp 5614-5624 (1981).

140. Pouget, J. and Maugin, G.A., "Piezoelectric Rayleigh Waves in Elastic Ferroelectrics," J. Acoust. Soc. Amer., 69 (5), pp 1319-1325 (1981).

141. Kazhis, R.I., "Frequency Responses of a Piezoelectric Shear-Mode Receiver with an Inhomogeneous Electric Field," Sov. Phys. Acoust., 26 (1), pp 39-43 (1980); Akust. Zh., 26, pp 74-83.

142. Korobov, A.I. and Lyamov, V.E., "Nonlinear Piezoelectric Coefficients of $LiNbO_3$," Sov. Phys. Solid State, 17 (5), pp 932-933 (1975); Fiz. Tverd. Tela., 17, pp 1448-1450.

143. Nakagawa, Y., Yamanouchi, K., and Shibayama, K., "Third-Order Elastic Constants of Lithium Niobate," J. Appl. Phys., 44 (9), pp 3969-3974 (1973).

144. Bell, J.F., "The Experimental Foundations of Solid Mechanics," Encyclopedia of Physics, Vol. VIa/1; Mechanics of Solids I, pp 1-813, Springer-Verlag (1973).

145. GOST (All-Union State Standard) 12370-72: Piezoceramic Materials. Testing Methods (in Russian), Izd. Standartov, Moscow (1973).

146. Baryshnikova, L.F. and Lyamov, V.E., "Elliptical Polarization of Acoustic Waves in Piezoelectric Crystals under the Action of an Electric Field," Sov. Phys. Acoust., 26 (6), pp 465-467 (1981); Akust. Zh., 26, pp 824-827.

147. Lerch, R. and Sessler, G.M., "Microphones with Rigidly Supported Piezopolymer Membranes," J. Acoust. Soc. Amer., 67 (4), pp 1379-1381 (1980).

148. Rosenberg, A. and Politch, J., "Investigation of of a Vibrating Piezoelectric Ceramic Disk by Synthesis of Optical Coherent Methods," Exptl. Mech., 20 (4), pp 140-144 (1980).

149. Ito, Y., Nagatsuma, K., Takeuchi, H., and Jyomura, S., "Surface Acoustic Wave and Piezoelectric Properties of (Pb, Ln) (Ti, Mn)O_3 Ceramics (Ln = rare earth)," J. Appl. Phys., 52 (7), pp 4479-4486 (1981).

150. Takeuchi, H. and Yamauchi, H., "Strain Effects on Surface Acoustic Wave Velocities in Modified $PbTiO_3$ Ceramics," J. Appl. Phys., 52 (10), pp 6147-6150 (1981).

151. Tanaka, H., Shimizu, H., and Yamada, K., "Methods for Energy Trapping of Thickness Extensional Mode and Thickness Shear Mode in Piezoelectric Ceramic Plate," Elec. Comm. Japan, 62-A (8), pp 10-19 (1981).

152. Tsok, O.E., "Influence of the Dimensions of Piezoelectric Plates on the Nature of Their Vibrational Modes," Sov. Phys. Acoust., 26 (6), pp 524-525 (1981); Akust. Zh., 26, pp 929-931.

153. Magdich, L.N. and Shnitser, P.I., "Structure of the Oscillations in an Open Acoustic Resonator with a Reflective Piezoelectric Transducer," Sov. Phys. Acoust., 27 (4), pp 313-315 (1982); Akust. Zh., 27, pp 562-566.

154. Lanina, E.P., "Tunable High-Frequency High-Power Piezoceramic Radiator," Sov. Phys. Acoust., 24 (3), pp 207-209 (1978); Akust. Zh., 24, pp 372-375.

155. Pajewski, W., "Transversal Bleustein-Gulayev (B.G.) Surface Waves on a Piezoelectric Ceramic," Arch. Acoust., 2 (3), pp 197-206 (1977).

156. Kinh, N.V. and Pajewski, W., "Generation of Acousto-electrical Waves Using a Source of Transverse Vibrations," Arch. Acoust., 5 (3), pp 261-274 (1980).

157. Karlash, V.L., Klyushnichenko, V.A., Kramarov, Yu.A., and Ulitko, A.F., "Radial Vibrations of Thin Piezoceramic Disks under a Nonuniform Electric Load," Sov. Appl. Mech., 13 (8), pp 784-788 (1977); Prikl. Mekh., 13, pp 56-62.

158. Karlash, V.L., "Radial Modes of Piezoceramic Disks with Open-Circuit Electrodes," Sov. Appl. Mech., 17 (9), pp 836-839 (1982); Prikl. Mekh., 17, pp 83-87.

159. Karlash, V.L., "Nonsymmetric Vibrations of Piezoelectric Ceramic Rings Polarized along the Thickness," Sov. Appl. Mech., 14 (12), pp 1303-1308 (1979); Prikl. Mekh., 14, pp 88-94.

160. Golanowski, J. and Gudra, T., "Ultrasonic Transducers Using Radial Vibrations of a Piezoelectric Disk," Arch. Acoust., 4 (3), pp 245-255 (1979).

161. Bogy, D.B. and Miu, D.K.K., "Transient Voltage across Axisymmetrically Loaded Piezoelectric Disks with Electroded Faces," J. Acoust. Soc. Amer., 71 (2), pp 487-497 (1982).

162. Burt, J.A., "The Response of a Fluid-filled Piezoceramic Cylinder to Pressure Generated by an Axial Laser Pulse," J. Acoust. Soc. Amer., 65 (5), pp 1164-1169 (1979).

163. Ricketts, D., Electroacoustic Sensitivity of Composite Piezoelectric Polymer Cylinders," J. Acoust. Soc. Amer., 68 (4), pp 1025-1029 (1980).

164. Tims, A.C., "Effects of Multidimensional Stress on Radially Polarized Piezoelectric Ceramic Tubes," J. Acoust. Soc. Amer., 70 (1), pp 21-28 (1981).

165. Lerch, R., "Electroacoustic Transducers Using Piezoelectric Polyvinylidenefluoride Films," J. Acoust. Soc. Amer., 66 (4), pp 952-954 (1979).

166. Lerch, R., "Piezopolymer Transducers with Point-Supported Membranes," J. Acoust. Soc. Amer., 70 (5), pp 1229-1234 (1981).

167. Sheiko, Yu.A., "Equivalent Circuit of a Flexurally Vibrating Multielectrode Piezoelectric Bar," Sov. Phys. Acoust., 24 (2), pp 154-156 (1978); Akust. Zh., 24, pp 279-283.

168. McNab, A. and Richter, J., "Electromagnetic Field Reciprocity Applied to the Excitation and Detection of Elastic Waves in an Electromagnetic Cavity Resonator," J. Acoust. Soc. Amer., 66 (6), pp 1593-1600 (1979).

169. Horvat, P. and Auld, B.A., "Propagation d'ondes de Cisaillement et d'ondes de Lamb dans les Films Piézoélectriques de Poly(fluorure de vinylidène)," C.R. Acad. Sci., 290, Série B, pp 1-4 (1980).

170. Tiersten, H.F., McDonald, J.F., Tse, M.F., and Das, P., "Monolithic Mosaic Transducer Utilizing Trapped Energy Modes," Acoustical Holography, Vol. 7, pp 405-422, Plenum Publ. Corp. (1977).

171. Tiersten, H.F., Sinha, B.K., McDonald, J.F., and Das, P.K., "On the Influence of a Tuning Inductor on the Bandwidth of Extensional Trapped Energy Mode Transducers," IEEE Ultrasonics Symp. Proc., pp 163-166 (1978).

172. Lee, D.L., "Analysis of Energy Trapping Effects for SH-Type Waves on Rotated Y-Cut Quartz," IEEE SU-28 (5), pp 330-341 (1981).

173. Watanabe, H., Nakamura, K., and Shimizu, H., "A New Type of Energy Trapping Caused by Contributions from the Complex Branches of Dispersion Curves," IEEE SU-28 (4), pp 265-270 (1981).

DIGITAL SYNTHESIS OF RESPONSE-DESIGN SPECTRUM COMPATIBLE EARTHQUAKE RECORDS FOR DYNAMIC ANALYSES

P-T.D. Spanos*

Abstract. ***Methods of digital synthesis (simulation) of earthquake records that are compatible with a target (specified) response-design spectrum are reviewed. The target spectrum can be specified either deterministically or stochastically. Some aspects of this problem that could receive additional attention are presented. The usefulness of a target spectrum-based approach to the design of earthquake resistant structures is addressed.***

The idea of characterizing earthquake records by using the concepts of response and design spectra has proved fruitful for about half a century. Some early discussions are available [1-4]. Furthermore, many books on earthquake engineering discuss these important concepts [5-10]. It has thus become routine to generate the response spectrum of a given earthquake record. In many practical cases, however, it is desirable to pose the inverse problem and to synthesize (simulate) earthquake records that are compatible with a target (specified) spectrum. The answer to this problem is not readily obtainable.

In this article concepts of spectral characterization of earthquake motions are first reviewed. Methods of generating spectrum compatible records are then discussed. A special effort has been made to cover the subject adequately while quoting only sources that are reasonably accessible to interested readers.

BACKGROUND

The most direct characterization of earthquake motion in the time domain is provided by accelerograms. An accelerogram is a time record of ground acceleration during an earthquake; it is commonly obtained by using instruments called strong-motion accelerographs. The accelerograph records three orthogonal components of ground acceleration at a certain loation.

An extensive collection of historic accelerograms and corresponding velocity and displacement records has been compiled [11]. A typical example is given in Figure 1. Information can be obtained from an accelerogram about duration, frequency content, and maximum acceleration of ground shaking during any earthquake under consideration. The strength of the ground shaking is characterized on an absolute basis. However, no direct assessment is provided of severity for a particular structure exposed to dynamic loads due to the earthquake.

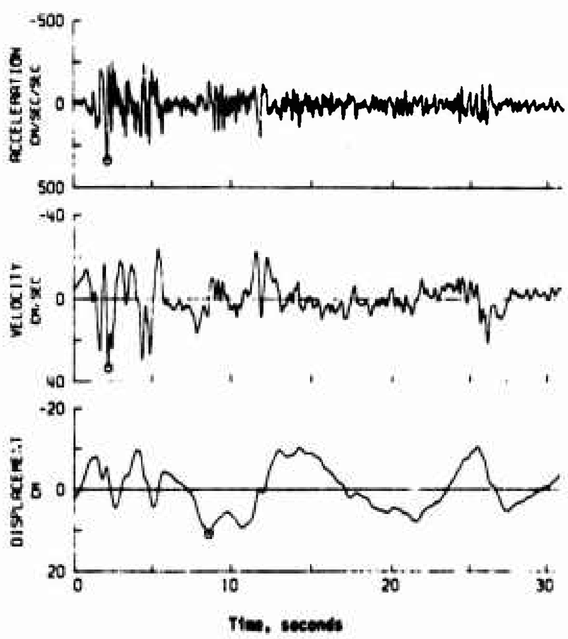

Figure 1. Imperial Valley Earthquake, May 18, 1940, El Centro Site, Component SOOE

Associate Professor of Engineering Mechanics, University of Texas at Austin, TX 78712

The severity of ground shaking also depends on the degree of both resistance to deformation and energy dissipation of the structure. For example, for single-degree-of-freedom linear structures with the same ratio of critical damping, the severity of ground shaking increases as the natural frequency of a structure approaches its dominant frequencies. Therefore, a quantitative description of the relative significance of various frequencies that appear in an accelerogram is important. This description is furnished by the Fourier spectrum of an accelerogram [5, 6]. The Fourier spectrum of a given accelerogram of ground motion $a_g(t)$ of duration s is defined by the equation

$$F(\omega) = \int_0^s a_g(t) e^{-i\omega t} dt;\ i = \sqrt{-1} \tag{1}$$

The Fourier amplitude spectrum is given by the equation

$$F_A(\omega) = |F(\omega)| \tag{2}$$

The symbol | | denotes complex modulus.

RESPONSE SPECTRUM

The Fourier spectrum does not directly provide information on the severity of ground shaking with regard to the energy dissipation capacity of a seismically loaded structure. Such information is provided by the response spectrum corresponding to a particular accelerogram [5-10]. A response spectrum is associated with the dynamic behavior of a quiescent single-degree-of-freedom structure resting on a base which is suddenly exposed to the acceleration history specified by the accelerogram under consideration; see Figure 2. The response spectrum provides the maximum values attained by such structural response parameters as displacement, velocity, or acceleration because of base shaking. The maxima are shown in plots versus natural frequency or period of the structure; each plot is identified by the ratio of critical damping ζ of the structure.

Mathematically, the concept of the response spectrum can be introduced by the following equation of motion of the linear structure

$$\ddot{x} + 2\zeta\omega\,\dot{x} + \omega^2 x = -\,a_g(t) \tag{3}$$

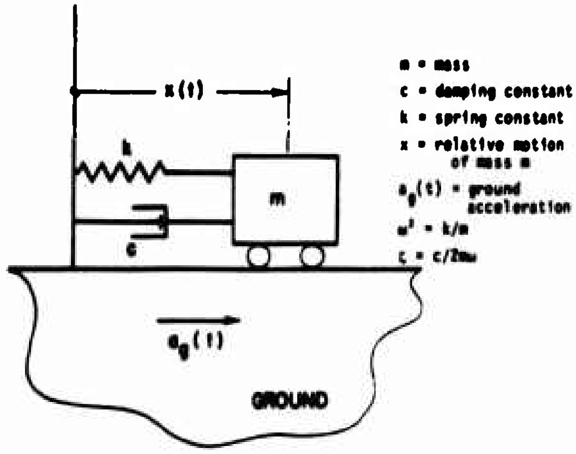

Figure 2. A Single-Degree-of-Freedom Structure to Earthquake Excitation

The relative displacement, velocity, and acceleration response spectra are defined by the following equations

$$\text{Displacement Response Spectrum} \equiv S_d(\omega,\zeta) = \text{Max}\,|x(t)| \tag{4}$$

$$\text{Velocity Response Spectrum} \equiv S_v(\omega,\zeta) = \text{Max}\,|\dot{x}(t)| \tag{5}$$

$$\text{Acceleration Response Spectrum} \equiv S_a(\omega,\zeta) = \text{Max}\,|\ddot{x}(t)| \tag{6}$$

Note that, if r(t) represents any of the responses appearing in equations (4) through (6), it can be determined by using the equation

$$r(t) = -\int_0^t a_g(\tau) h(t-\tau) d\tau \tag{7}$$

in which $h(\tau)$ denotes the impulse response function of the structure for any particular response considered. Commonly used response spectra are concerned with relative displacement, relative velocity, and absolute acceleration.

In fact, because of the small ratio of critical damping in the linear range of most engineering structures -- approximately $\leq$ 3% for buildings and $\leq$ 5% for soils -- relative velocity and absolute acceleration response spectra are approximated by the pseudo-velocity spectrum $\omega S_d(\omega,\zeta)$ and the pseudo-acceleration spectrum $\omega^2 S_d(\omega,\zeta)$. Typically, the logarithms of pseudo-velocity spectral ordinates are plotted against the logarithms of the natural period or frequency of the structure. Also included are ascending and descending lines at 135° and 45° angles; the frequency axis corresponds to the logarithms of the displacement and pseudo-acceleration spectral ordinates. Thus, a combined tripartite logarithmic plot is generated. A typical example of such a plot is shown in Figure 3, which is based on the accelerogram shown in Figure 1. An extensive collection of response spectra of historic accelerograms is available [12].

If the natural frequency ω and the ratio of critical damping ζ of a linear structure are known, the maximum value of a parameter of its response to base seismic excitation -- maximum base shear for example -- can be conveniently computed from the corresponding response spectrum. The significance of this convenience is enhanced by the fact that a large class of multi-degree-of-freedom structures are amenable to modal analysis. The structural response to a dynamic load such as earthquake excitation can thus be determined by combining appropriately the seismic responses of a set of single-degree-of-freedom

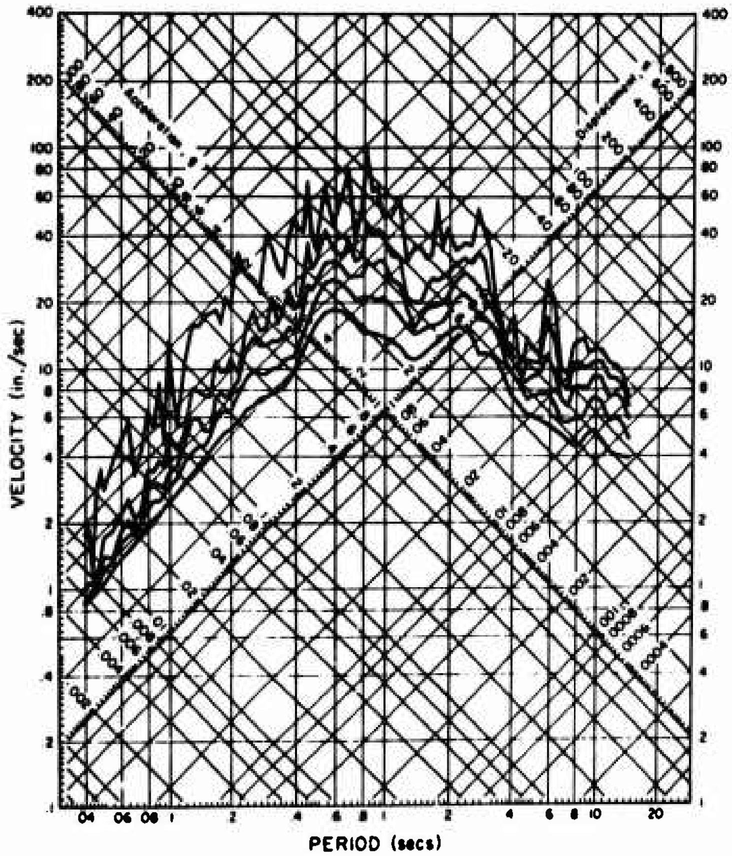

Figure 3. Response Spectrum; Imperial Valley Earthquake, May 18, 1940, El Centro Site, Component SOOE; ζ = 0, .02, 0.5, 0.10, and 0.20

oscillators. The natural frequencies and the ratios of critical damping of these oscillators depend on the mass, stiffness, and damping matrices of the original multi-degree-of-freedom structure.

DESIGN SPECTRUM

The response spectrum corresponding to a particular accelerogram exhibits considerable local irregularities in the frequency domain. However, spectra corresponding to an ensemble of accelerograms produced by ground shakings of sites with similar geological and seismological characteristics are smooth functions of time and exhibit statistical trends that characterize them collectively. For example, the band of dominant-significant frequencies of accelerograms is identifiable on a statistical basis. Thus, if an approach based on the concept of response spectrum is adopted for aseismic design of structures, it is logical to seek a representation of recorded and expected strong ground shaking at a certain location by using a smooth spectrum. This spectrum is on the one hand insensitive to the chaotic details of any particular response spectrum; on the other hand, it reflects the repetitive characteristics of the ensemble of response spectra. This idea has led to the development of the concept of a design spectrum. A typical example of a design spectrum is given in Figure 4 [10].

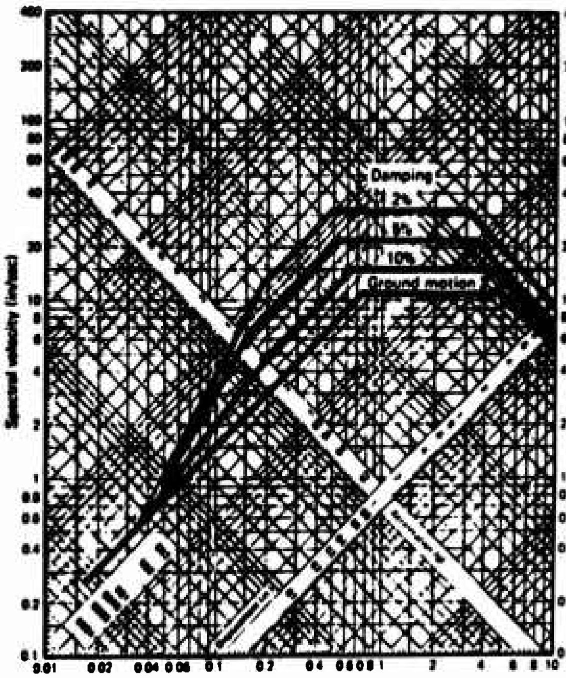

Figure 4. Example of a Combined Design Spectrum

Development or selection of a proper design spectrum for a given erection site of a structure is not an easy task. It involves the incorporation of historical data, available and extrapolated theoretical results, and engineering judgement. Discussions of background information useful in determining expected ground shaking of given erection sites are available [13-14].

A design spectrum can be specified on either a deterministic or a stochastic (probabilistic) basis [15-23]. Related to the concept of the design spectrum is the concept of a critical design spectrum [24-28]. A deterministic design spectrum is developed by using smoothing procedures to eliminate insignificant local abrupt changes in the response spectra of individual recorded accelerograms, and known and extrapolated theoretical results.

A stochastic design spectrum is associated with the interpretation of any recorded or expected ground shaking record at a given location as an individual realization, or sample function, of a time series. A stochastic design spectrum can then be generated by specifying, with a selected confidence level, the expected maximum response of a single-degree-of-freedom linear structure as a function of its natural frequency and ratio of critical damping. However, for this purpose it is necessary to know the probability distribution of the maximum of the structural response; this problem is equivalent to the first-passage problem of the theory of random vibrations [29] for which only approximate analytical solutions exist. Therefore, a stochastic spectrum is often constructed numerically, and only its mean value and standard deviation are specified.

A critical design spectrum is associated with the idea of determining an excitation among a certain group of excitations that will induce the largest peak value of any parameter of interest in the structural response. The class of admissible excitations and the measure of the response parameter of interest can be specified either deterministically or stochastically.

For example, a class of admissible excitations can be defined as containing all accelerograms $a_g(t)$ for which

$$\int_0^D a_g^2(t)dt \leq E_1^2 \tag{8}$$

or

$$\int_0^D \langle a_g^2(t) \rangle dt \leq E_2^2 \tag{9}$$

The symbols E_1 and E_2 denote constants, D is an accelerogram duration parameter, and the symbol $\langle \cdot \rangle$ represents the operator of mathematical expectation.

ALGORITHMS OF DIGITAL SYNTHESIS

The usefulness of spectral characterizations of expected strong ground shaking at erection sites of presumably linearly responding structures is undisputable and has resulted in the accumulation of such characterizations. Consequently, spectral characterizations of seismic loads have been recommended or adopted for dynamic analyses of even nonlinear structures. Their nonlinear behavior is usually due to geometrical and material factors. Typical examples of nonlinear structures are nuclear power plants and offshore platforms.

Nonlinear seismic dynamic analyses of structures rely almost exclusively on digital computers to integrate the corresponding equations of motion. It, therefore, becomes necessary to develop an algorithm that synthesizes accelerograms compatible with target design spectra. The development of these algorithms can be accomplished by following either a deterministic or a stochastic approach.

Deterministic approach. An early deterministic approach has been presented in connection with procedures of aseismic design of nuclear power plants [30]. The synthesis procedure, described only qualitatively, starts with an accelerogram of an actual earthquake the response spectrum of which resembles the target response spectrum. This accelerogram is scaled so that the maximum of its response spectrum matches the maximum of the target response spectrum. Matching between the two spectra is enhanced by changing the digitization interval, using analog filtering techniques, and manipulating algebraically more than one synthesized record.

A basically similar approach but one that is more quantitative has also been used [31]. An existing accelerogram with a response spectrum matching the target spectrum in many respects is first utilized. This spectrum is modified by using a two-degree-of-freedom mechanical filter to suppress undesirable frequencies. The level of the spectrum is raised locally by superimposing on the selected accelerogram harmonic components of appropriate amplitude, central frequency, and phase.

Existing accelerograms have also been used to initiate the synthesis procedure when existing earthquake records are represented in the frequency domain by using the corresponding Fourier transforms [32]. The basic reason for this approach is that the amplitude Fourier spectrum shown in equation (2) and the velocity response spectrum for zero ratio of critical damping ζ of any accelerogram are in a close agreement [4]. Conceivably, a similarity between these two spectra can exist even for $\zeta \neq 0$.

Thus, an existing earthquake record is selected and its amplitude Fourier spectrum and response spectrum are computed. Next, the response spectrum is compared against the target spectrum; the difference is used to modify the amplitude Fourier spectrum. The modification involves either scaling by a function of frequency or adding a function of frequency. This method is iterative and can accommodate simultaneously the additional constraint that the peak acceleration of the synthesized time history has a pre-assigned value.

The synthetic record has been represented as the product of a modulating envelope and a sum of harmonic functions [33]. The following equation was used

$$a_g(t) = m(t) \sum_{i=1}^{N} A_i \sin(\omega_i t) \tag{10}$$

The frequencies ω_i of the harmonic functions were selected so that they had overlapping half-power points for the ratio of critical damping of the target spectrum. The number N of these frequencies chosen was based on the band of frequencies over which the target spectrum had appreciable values. The modulating envelope m(t) was selected by using the time variation of the strength of actual earthquakes such as the 1940 El Centro earthquake. The amplitudes A_i of the harmonic functions were initially estimated by using the values of the target spectrum corresponding to the frequencies ω_i. The values of A_i were subsequently scaled by the ratio of the target to the synthesized spectrum which corresponded to ω_i.

Two other aspects of accelerogram synthesis were considered [33]. One deals with the question of existence of a time record that is compatible with any arbitrary response spectrum; in fact, one spectrum does not have a compatible time history. The other aspect has to do with the simultaneous simulation of two uncorrelated time records.

It has been proposed that a simple sinusoid with variable frequency, a sine sweep earthquake, be used to synthesize a very short accelerogram with a response spectrum matching a target spectrum corresponding to a much longer actual earthquake [34]. The specific form of the synthesized accelerogram is given by the equation

$$a_g(t) = A(\omega) \sin [\theta(t)] \tag{11}$$

$A(\omega)$ is a function of frequency, and $\theta(t)$ is a nonlinear function of time.

This approach has been exemplified by simulating a sine sweep accelerogram that is compatible with the response spectrum of a specific record of the 1940 El Centro earthquake. For this particular problem $\theta(t)$ was taken equal to an odd cubic function of time. The amplitude $A(\omega)$ was defined piecewise and involved a linear function for small frequencies, a constant for intermediate frequencies, and the cubic power of the square root of ω for high frequencies.

Interestingly, the sine sweep earthquake of duration of three seconds yielded a response spectrum that compares quite well with the response spectrum of the recorded El Centro accelerogram, which lasts approximately thirty seconds. Conceivably, the capability of the sine sweep accelerogram to quickly induce large responses on structural systems, could be of considerable value in reducing the necessary computation cost of time domain analyses of major structures. Useful discussions pertaining to these techniques and to the stochastic techniques discussed in the next section are available [35].

Stochastic approach. An alternative to the deterministic approach to synthesizing spectrum compatible accelerograms is the stochastic approach. In this approach attention is given to two different but related problems. The first problem has to do with the synthesis of a record that is a realization of a stochastic process and is compatible with a given deterministic response spectrum. The second problem pertains to the synthesis of a stochastic process with a probabilistically specified response spectrum.

As far as the first problem is concerned, a method has been presented [36] to synthesize an earthquake record as a time-modulated sum of harmonic functions with random phases uniformly distributed in the interval $(0, 2\pi)$. The duration D_0 of the accelerogram was preselected, and the acceleration at a time t was computed from equation (12).

$$a_g(t) = m(t) \sum_{i=1}^{N} A_i \cos\left(\frac{2\pi i t}{D_0} + \phi_i\right) \tag{12}$$

The symbol m(t) signifies a deterministic modulating envelope of the form [37]

$$m(t) = \begin{cases} \left(\dfrac{t}{t_1}\right)^2 ; & 0 < t < t_1 \\ 1 ; & t_1 < t < t_2 \\ \exp[-\alpha(t-t_2)] ; & t_2 < t < D_0 \end{cases} \tag{13}$$

where t_1, t_2, and α are preselected parameters. The form of the modulating envelope given by equation (1:' reflects three phases of the strength of strong ground shaking. The strength of the ground motion increases rapidly between zero and t_1, remains constant between t_1 and t_2, and decreases exponentially after t_2. This model has been used extensively in the literature in connection with stochastic modeling of earthquakes.

The symbol ϕ in equation (12) signifies a random phase uniformly distributed in the interval $[0, 2\pi]$. For the purpose of generating ϕ_i several available algorithms can be used. A typical example has been published [38]. Values from the target spectrum corresponding to zero damping were selected as initial estimates of the amplitudes A_i of the harmonic functions. Final values of the amplitudes were selected through an iterative procedure that involved scaling A_i by the ratio of the target over the synthesized spectrum at $\omega = \omega_i$. A similar approach that does not involve use of the modulating envelope m(t) has been presented [39].

Another approach involves a combination of time domain and frequency domain techniques [40]. Attention was also given to the problem of synthesizing an accelerogram that is simultaneously compatible with a design spectrum and a peak acceleration value. In a similar approach [41] the accelerogram was represented again as the product of a modulating envelope and a sum of harmonic functions with random phases. The modulating envelope was of the form [42]

$$m(t) = e^{-\beta t} - e^{-\gamma t}; \; 0 < \beta < \gamma \qquad (14)$$

This envelope has been extensively used in connection with stochastic modeling of earthquakes. The amplitudes and random phases of the harmonic components are determined through an iterative procedure and by relying on a relationship which assures that the spectrum of the synthesized record is an upper bound of the target spectrum. The problem of synthesizing an accelerogram that is simultaneously compatible with target spectra corresponding to two different damping ratios was also addressed.

As far as the second problem is concerned, reported solution techniques seek to determine the power spectral density of a stochastic process that is compatible, in a certain probabilistic sense, with a target response spectrum. The power spectral density of a stochastic process shows, on a statistical basis, the distribution of power versus frequency; it reflects the band of frequencies that appreciably contribute to the power of the process and quantifies their relative importance [29]. For example, the mean square value of a stochastic model of accelerograms $a_g(t)$ is given by the equation

$$< a_g^2(t) > = \int_{-\infty}^{\infty} S_g(\omega,t)d\omega \; ; \qquad (15)$$

$S_g(t)$ is the power spectral density of $a_g(t)$.

For the purpose of deducing the power spectral density from a target spectrum, exact and approximate solutions for the response of a single-degree-of-freedom structure to a random excitation can be used. Approximate solutions for determining the probability distribution of the maximum of the random structural response over a certain duration of excitation are employed. These solutions pertain either to first-passage problems [23, 43-46] or to the maximum of a statistical moment of a structural response parameter [47-49]. Advantage is often taken of the fact that design spectra are usually specified for lightly damped ($\zeta << 1$) structures.

These approaches can be used to determine the power spectral density of a stochastic process for which the average of the response spectra corresponding to its realizations matches the target spectrum. A more general criterion can also be satisfied such that a preselected fraction of the realizations of the stochastic process yield response spectra that exceed the target spectrum at all frequencies of interest. In fact, some researchers prefer to use this approach to select an initial approximation of an accelerogram that matches a deterministic target spectrum. For example, the power spectral density of the stochastic process can be determined so that the median of the corresponding population of response spectra approximates the target spectrum. A single accelerogram can be synthesized that is compatible with the determined power spectral density and then modified so that its response spectrum matches the target spectrum.

Insofar as the synthesis of an accelerogram that is compatible with a specified two-sided power spectral density $S_g(\omega,t)$ is concerned, the most direct approach is based on the equation

$$a_g(t) = \sum_{i=1}^{\ell} 2\sqrt{S(\omega_i,t)\Delta\omega}\,\cos(\omega_i t + \phi_i); \qquad \Delta\omega = \frac{\omega_u}{\ell} \qquad (16)$$

where ℓ is an integer, ω_u is the upper limit of the frequency band of interest, and ϕ_i are random phases uniformly distributed in the interval $[0, 2\pi]$. Other equivalent versions of equation (16) can also be used.

CONCLUDING REMARKS

Methods that can be used for synthesizing time records compatible with specified response-design spectra have been reviewed. The two basic approaches to this problem are deterministic and stochastic. The deterministic approach is based on a real or artificial record the spectrum of which is, in some quantitative sense, a close approximation of the target spectrum. This record is subsequently modified using spectral raising or suppressing techniques. The stochastic approach is based on determining the power spectral density of a process, a realization of which can be a good first approximation of the record sought in a deterministic formulation of the problem. The stochastic approach can also be used for the case in which a deterministic target spectrum is not specified; rather, a process is sought a predetermined fraction of records of which yield response spectra that exceed a given design spectrum.

This reviewer would like to call attention to two related points of the problem of synthesis of target response-design spectrum compatible records. First, it seems that this problem has not been addressed on a mathematically rigorous basis. Apart from one notable exception [33] little concern has been expressed about the existence and uniqueness, in any reasonable sense, of a time history record that is compatible with an arbitrary single target spectrum or simultaneously compatible with arbitrary target spectra corresponding to more than one ratio of critical damping. Second, the practicality of continuing to specify seismic inputs in dynamic analyses of structural systems by a design spectrum is questioned. The concept of design spectrum has been introduced for the purpose of conducting conveniently linear dynamic seismic analyses of structures. In a sense the analyst or the code developer that specifies a certain design spectrum has carried out in advance some of the computations that a practitioner would have to perform. This is an intelligent approach to a linear problem.

However, for the nonlinear seismic analyses of modern structures that have become feasible with digital computers -- indeed almost mandatory due to cost and safety considerations -- the concept of a design spectrum does not offer any advantage. Thus, a more rational and reasonably convenient procedure for specifying expected seismic loads should be adopted, a procedure that is applicable for both linear and nonlinear analyses. Either the time-history record of the acceleration or the corresponding Fourier spectrum could be used.

Alternatively, on a stochastic basis the power spectral density of the ground shaking could be specified. This approach has considerable appeal when two facts are taken into consideration. First, records compatible with a specified power spectral density can be readily synthesized. Second, reliable estimates of the statistics of elastic and inelastic nonlinear random seismic responses of multi-degree-of-freedom structures can be efficiently computed by using the technique of stochastic linearization [50].

ACKNOWLEDGEMENT

The author would like to express his gratitude to the Earthquake Hazards Mitigation Program of the National Science Foundation for sustained financial support of his research program on earthquake engineering. Thanks are due to Professor J. Roesset for making several constructive comments.

REFERENCES

1. Benioff, H., "The Physical Evaluation of Seismic Destructiveness," Bull. Seismol. Soc. Amer., 24, pp 398-403 (1934).

2. Biot, M.A., "A Mechanical Analyzer for the Prediction of Earthquake Stresses," Bull. Seismol. Soc. Amer., 31, pp 151-171 (1941).

3. Housner, G.W., Martel, R.R., and Alford, J.L., "Spectrum Analysis of Strong-Motion Earthquakes," Bull. Seismol. Soc. Amer., 43, pp 97-119 (1953).

4. Hudson, D.E., "Some Problems in the Application of Spectrum Techniques to Strong-Motion Earthquake Analysis," Bull. Seismol. Soc. Amer., 52 (2), pp 417-430 (Apr 1962).

5. Wiegel, R.L. (coordinating editor), Earthquake Engineering, Prentice Hall (1970).

6. Newmark, N.M. and Rosenblueth, E., Fundamentals of Earthquake Engineering, Prentice Hall (1971).

7. Dowrick, D.J., Earthquake Resistant Design, John Wiley and Sons (1977).

8. Green, N.B., Earthquake Resistant Building Design and Construction, Van Nostrand Reinhold (1978).

9. Rosenblueth, E. (editor), Design of Earthquake Resistant Structures, John Wiley and Sons (1981).

10. Englekirk, R.E. and Hart, G.C., Earthquake Design of Concrete Masonry Buildings, Vol 1, Prentice-Hall (1982).

11. California Institute of Technology, Earthquake Engineering Research Laboratory, "Strong Motion Earthquake Accelerograms," Vol II (1971).

12. California Institute of Technology, Earthquake Engineering Research Laboratory, "Strong Motion Earthquake Accelerograms," Vol III (1972).

13. Lomnitz, C. and Rosenblueth (editors), Seismic Risk and Engineering Decisions, Elsevier (1976).

14. Werner, S.D., "Engineering Characteristics of Earthquake Ground Motions," Nucl. Engrg. Des., 36, pp 367-395 (1976).

15. Housner, G.W., "Behavior of Structures during Earthquakes," ASCE J. Engrg. Mech. Div., 89 (EM4), pp 109-129 (1959).

16. Bycroft, G.N., "White Noise Representation of Earthquakes," ASCE J. Engrg. Mech. Div., 86 (EM2), pp 1-16 (Apr 1960).

17. Rosenblueth, E. and Bustamante, J.I., "Distribution of Structural Response to Earthquakes," ASCE J. Engrg. Mech. Div., 88 (EM3), pp 75-106 (June 1962).

18. Housner, G.W. and Jennings, P.C., "Generation of Artificial Earthquakes," J. Engrg. Mech. Div., 90 (EM1), pp 113-140 (Feb 1964).

19. Newmark, N.M., Blume, J.A., and Kapur, K.K., "Seismic Design Spectra for Nuclear Power Plants," ASCE J. Power Div., 99 (PO2), pp 287-303 (Nov 1973).

20. Seed, H.B., Ugas, C., and Lysmer, J., "Site-Dependent Spectrum for Earthquake Resistant Design," Bull. Seismol. Soc. Amer., 66, pp 221-243 (1976).

21. Kiremidjian, A.S. and Shah, H.C., "Probabilistic Site-Dependent Response Spectra," ASCE J. Struc. Div., 106 (ST1), pp 69-86 (Jan 1980).

22. Spanos, P-T.D., "Probabilistic Earthquake Energy Spectra Equations," ASCE J. Engrg. Mech. Div., 106 (EM1), pp 147-159 (Feb 1980).

23. Yang, J.N. and Liu, S.C., "Distribution of Maximum and Statistical Response Spectrum," ASCE J. Engrg. Mech. Div., 107 (EM6), pp 1089-1102 (Dec 1981).

24. Shinozuka, M., "Maximum Structural Response to Seismic Excitations," ASCE J. Engrg. Mech. Div., 96 (EM5), pp 729-737 (1970).

25. Drenick, R.F., "Model-Free Design of Aseismic Structure," ASCE J. Engrg. Mech. Div., 96, pp 483-493 (1970).

26. Drenick, R.F., "Aseismic Design by Way of Critical Excitation," ASCE J. Engrg. Mech. Div., 99, pp 649-667 (1973).

27. Wang, P.C., Drenick, R.F., and Wang, W., "Seismic Assessment of High-Rise Buildings," ASCE J. Engrg. Mech. Div., 104, pp 441-451 (1978).

28. Wang, P.C. and Yun, C.B., "Site-Dependent Critical Design Spectra," Intl. J. Earthquake Engrg. Struc. Dynam., 7, pp 569-578 (1979).

29. Lin, Y.K., Probabilistic Theory of Structural Dynamics, Krieger (1976).

30. Hadjian, A.H., "Scaling of Earthquake Accelerograms -- A Simplified Approach," ASCE J. Struc. Div., 98 (ST2), pp 547-551 (Feb 1972).

31. Tsai, N-C., "Spectrum-Compatible Motions for Design Purposes," ASCE J. Engrg. Mech. Div., 98 (EM2), pp 345-356 (Apr 1972).

32. Rizzo, P.C., Shaw, D.E., Jarecki, S.J., "Development of Real/Synthetic Time Histories to Match Smooth Design Spectra," Nucl. Engrg. Des., 32, pp 148-155 (1975).

33. Levy, S. and Wilkinson, J.P.D., "Generation of Artificial Time-Histories, Rich in All Frequencies, from Given Response Spectra," Nucl. Engrg. Des., 38, pp 241-251 (1976).

34. Johnson, G.R. and Epstein, H.I., "Short Duration Analytic Earthquake," ASCE J. Struc. Div., 102 (ST5), pp 993-1001 (1976).

35. Ahmadi, G., "Generation of Artificial Time-Histories Compatible with Given Response Spectra -- A Review," Solid Mech. Arch., 4 (3), pp 207-239 (Aug 1979).

36. Scanlan, R.H. and Sachs, K., "Earthquake Time-Histories and Response Spectra," ASCE J. Engrg. Mech. Div., 100 (EM4), pp 635-655 (1974).

37. Amin, M. and Ang, A.H-S., "Nonstationary Stochastic Model of Earthquake Motions," ASCE J. Engrg. Mech. Div., 94 (EM2), pp 559-583 (Apr 1968).

38. Forsythe, G.E., Malcolm, M.A., and Moler, C.B., Computer Methods for Mathematical Computations, Prentice-Hall (1977).

39. Romstad, K.M., Bruce, J., and Hutchinson, J.R., "Site Dependent Earthquake Motions," ASCE J. Geotech. Engrg. Div., 104 (GT11), pp 1389-1400 (Nov 1978).

40. Kost, G., Tellkamp, T., Kamil, H., Gantayat, A., and Weber, F., "Automated Generation of Spectrum-Compatible Time Histories," Nucl. Engrg. Des., 45, pp 243-249 (1978).

41 Ygengar, R.N. and Rao, P.N., "Generation of Spectrum Compatible Accelerograms," Intl. J. Earthquake Engrg. Struc. Dynam., 7, pp 253-263 (1979).

42. Shinozuka, M. and Sato, Y., "Simulation of Nonstationary Random Process," ASCE J. Engrg. Mech. Div., 93 (EM1), pp 11-40 (1967).

43. King, A.C.Y. and Chen, C., "Interactive Artificial Earthquake Generation," Computers Struc., 7, pp 503-506 (1977).

44. Vanmarcke, E.H. and Gasparini, D.A., "Simulated Earthquake Ground Motions," Proc. Struc. Mech. Reactor Tech. - 4, San Francisco, Paper K1/9, pp 1-12 (1977).

45. Preumont, A., "A Method for Generation of Artificial Earthquake Accelerograms," Nucl. Engrg. Des., 59, pp 357-368 (1980).

46. Iwan, W.D. and Mason, A.B., "A Statistical Technique for Relating Earthquake Time Histories and Response Spectra," Proc. Seventh World Conf. Earthquake Engrg., September 8-13, 1980, Istanbul, Turkey, 6, pp 673-680.

47. Levy, R., Kozin, F., and Moorman, R.B.B., "Random Processes for Earthquake Simulation," ASCE J. Engrg. Mech. Div., 97 (EM2), pp 495-517 (1971).

48. Spanos, P-T.D., "Response Spectra of Evolutionary Earthquake Models," Proc. Seventh World Conf. Earthquake Engrg., September 8-13, 1980, Istanbul, Turkey, 2, pp 387-390.

49. Spanos, P-T.D. and Lutes, L.D., "Probability of Response to Evolutionary Process," ASCE J. Engrg. Mech. Div., 106 (EM2), pp 213-224 (Apr 1980).

50. Spanos, P.D., "Stochastic Linearization in Structural Dynamics," Appl. Mech. Rev., 34 (1), pp 1-8 (Jan 1981).

BOOK REVIEWS

IMPACT DYNAMICS

J. Zukas, T. Nicholas, H.F. Swift, L.B. Greszuk, and D.R. Curran
John Wiley and Sons, Inc., New York, NY
1982, 480 pp, $47.50

This book grew out of a short course on the subject of impact dynamics initiated by the authors in 1979. The book is divided into 11 chapters. Contributors include the five authors participating in the lecture program; two of them contributed more than 75 percent of the text, which is directed toward the practicing engineer. Both experimental and analytical approaches are emphasized. A chapter by chapter summary of the material is given below.

Chapter 1 presents an overview of one-dimensional stress waves in solids. A range of loading intensities that can be classified in terms of specific response regimes is considered. The regimes are the purely elastic, the plastic involving large deformations, and the hydrodynamic. The first and third regimes are discussed in Chapter 1; discussion of the second regime is deferred to Chapter 4.

The focus of Chapter 2 is the limitations of the elementary analytical approach. Examples include the differences between liquid-solid impacts, fracture with stress waves, and the dynamic plastic buckling of long bars. The material is highly selective but well covered.

Chapter 3 examines damage in composites at low velocity impacts. It does not address the composite impact problem in broad terms but focuses on a narrower problem of interest to the author. This is unfortunate due to the technological importance of the problem area. For example, no definition of the scope of the foreign-object damage problem is discussed nor is any reference made to the number of joint industry/service/institutional meetings that have addressed this matter.

Chapter 4 deals with the second dynamic response regime, namely the elastic-plastic area. Analytical and and experimental methods are discussed for both rate-independent and rate-dependent theories. The chapter focuses on uniaxial stress wave propagation in long bars and rods. The method of characteristics is used as a mathematical tool in solving the governing equations. Difficulties can arise in measuring dynamic properties from uniaxial stress wave propagation in bars and rods; thus, analytical and experimental methods involving elastic-plastic waves of uniaxial strain using impacted flat plate specimens are developed. The theories are compared, and the effects of stress waves in other geometries such as strings and beams are discussed.

Chapter 5 presents a descriptive overview of penetration and perforation problems for impacting solids. A description of the problem, a classification of impact response, and discussion of physical phenomena involved during the penetration/perforation process are adequately documented. Thin, intermediate, and semi-infinite thickness targets are covered. Appendices address parameters associated with the ballistic limit and impactor stability.

Chapter 6 discusses the subject of hypervelocity impact mechanics; the problem is classified by target thickness. Because hypervelocity impacts produce shock waves in both the impactor and target materials, each medium can be considered to deform according to the laws of fluid mechanics. The first part of the chapter addresses the impact issue from a scaling/parameterization point of view; penetration/depth ratios are presented. The last part of the chapter examines the equipment needed to generate hypervelocity launches, including multi-staged gas guns, explosive projectors, and electrical accelerators.

Chapter 7 examines camera type devices for studying dynamic loading events associated with impact and blast loads. Design requirements as well as camera types are reviewed. Single-frame cameras including conventional, spark shadowgraph, and flash radiograph as well as other special techniques are described. Among the high-speed motion cameras discussed are the rotating prism, rotating mirror-drum, spark, and electronic tube type. Smear and streak type cameras are included for completeness.

Chapter 8 examines dynamic effects over a regime in which wave propagation effects can be considered either in a simplistic manner or ignored. Thus, this chapter examines situations in which stress and strain averaging are considered important. The split Hopkinson pressure bar is an accepted experimental tool for determining high strain rate material effects. Methods of pressure bar testing at high strain rates in compression, tension, and shear are discussed as are modified tests that extend strain rate performance limits beyond usually accepted bounds. Examples include direct impact versions of the pressure bar/specimen interaction and the use of such modified specimens as notched types. Other experimental techniques for quantifying particular dynamic properties data, including Taylor cylinder tests, expanding rings, dynamic shear, and bend tests, are also discussed. The chapter concludes with a section on constitutive equation modeling to describe dynamic material effects.

Chapter 9 discusses the dynamic fracture of materials. Both the classical fracture mechanics approach associated with macroscopic crack growth and the microstatistical approach involving microvoid concentration and size distribution functions are described. The chapter emphasizes the second approach; examples and applications are given for both ductile and brittle materials. An expansion of this chapter to include additional material applications would be welcome

Chapters 10 and 11 discuss computational methods and codes that describe high velocity impact phenomena. Chapter 10 examines the computational process, discretization procedures, and mesh descriptions necessary to formulate numerical solutions. Applications to problems are presented, and solution limitations are defined.

The final chapter lists the various codes presently in wide use; type, overall computational limits, and merit are given for each code. This chapter should be useful to the practicing engineer requiring such information to solve a particular problem.

In summary, this book is a useful reference for the practicing engineer who requires information on the subject of impact dynamics. Some chapters present a more comprehensive overview than others both in treatment of material and citation of relevant contributions. Also, as is true with any book of more than one author, an ordered alternative organization of the individual chapters would be useful. In this case Chapters 1, 2, and 4 should be grouped together followed by 8, 6, 7, 5, 10, and 11 and finally Chapters 9 and 3.

R.L. Sierakowski
University of Florida
Gainsville, FL 32611

TRENDS IN SOLID MECHANICS

J.F. Besseling and A.M.A. Van der Heijden, editors
Delft University Press, Sijthoff & Noordhoff
International, The Netherlands
1960, 246 pp, $45.00

This book contains the proceedings of a three-day symposium at the Delft University of Technology, The Netherlands, in June, 1979. The symposium was held to honor Professor W.T. Koiter on his 65th birthday. Thirteen invited speakers prominent in their fields presented the state of the art of a number of topics in the area of solid mechanics. These include elastic stability and theory of plasticity, nonlinear shell theory and nonlinear vibrations, reliability of structures, thermo-mechanics, and mathematical and finite element methods. The book begins with a biographical note and a list of publications of Professor Koiter. A brief review of the 13 papers follows.

1. "Elastic Wave Propagation Problems in Nondestructive Evaluation" by J.D. Achenbach. The integral equations governing the crack-opening displacements for both interior and surface breaking cracks are derived. These equations are solved numerically for specific geometries. The solution for the amplitude-spectrum is compared with the experimental results for longitudinal diffracted waves.

2. "Continuum Thermo-Mechanics" by B. Becker. This paper is related to the classical theory of

Caratheodory and Born. It deals with the local equilibrium and irreversible processes in continuum mechanics. Gibbs' relation of maximum entropy principle, visco-elasticity, and creep are described.

3. "Finite Element Methods" by J.F. Besseling. Finite element methods are reviewed with reference to linear structural mechanics. The paper includes solution procedures, the principles of virtual work and virtual heat, spatial finite element equations, the stability of structures, and kinematics of mechanisms.

4. "Reliability of Structures" by V.V. Bolotin. Professor Bolotin presents a survey of the general concepts and methods of the theory of structural reliability. The survey outlines stochastic models of structural failure, methods of evaluating reliability and longevity factors, and prediction of individual reliability and life factors.

5. "Buckling: Progress and Challenge" by B. Budiansky and J.W. Hutchinson. The authors discuss the general theory of elastic buckling. The paper describes the influence of the early work of Koiter on the development of the theory of buckling. In that regard the authors mention that "the general theory of elastic buckling and post-buckling behavior was presented by Koiter in his 1945 Ph.D. thesis. After a dormant period of over fifteen years the basic ideas of theory started to become widely known, and by now have become the subject of numerous alternative (but essentially equivalent) expositions." The paper indicates the importance of considering the bifurcation modes interaction because optimum design tends to produce structures having nearly equal resistances to more than one mode of failure. The plastic buckling associated with bifurcation in the plastic range, post-bifurcation behavior, and imperfection sensitivity are reviewed. The paper concludes with some observations on such related topics as optimum design, stochastic buckling, and the general stability theory.

6. "Nonlinear Vibration" by C. Hayashi. The author describes forced oscillatory systems with one and two degrees of freedom. The stability of periodic solutions is analyzed using Hill's equation and Floquet's theorem. Although solid mechanics is the main theme of the symposium, Professor Hayashi demonstrates his nonlinear analysis with the aid of electric circuits with a saturated inductance following the same lines of thought of his book. He then outlines the relationship between the initial condition and the resulting response by considering the transient state of oscillation before it settles into the steady state.

   Hayashi employed two methods to obtain the response curves. The first is the graphical solution of integral curves in the state plane; the second utilizes a mapping procedure based on the transformation theory of differential equations.

7. "Developments in the Mathematical Theory of Plasticity" by H.G. Hopkins. This paper deals with the mathematical theory of plasticity for cases involving either two space variables (quasi-static problems) or one space variable and time (dynamic problems).

8. "Models for High Temperature Fracture" by F.A. Leckie. The author describes possible mechanisms that influence the growth of cracks in metals operating at temperatures high enough for time-dependent effects to be important. The author suggests that in some situations the life of the component is dictated by considerations of continuum damage mechanics; in others it is dominated by the growth of cracks.

9. "Some Mathematical Problems Connected with Solid Mechanics" by J.L. Lions. The author outlines two abstract methods based on functional analysis. These methods are the variational in equalities and the asymptotic expansion for periodic structures. They are applied to the classical obstacle problem, theory of plasticity, and perforated materials.

10. "Variational Methods in Optimization of Structures" by F. Niordson and N. Olhoff. The authors analyze the existence of solutions as related to the actual formulation of the problem. This requires the study of continuity, singularities, jump-conditions, and bimodality. The paper introduces an approach to optimiza-

tion of reinforced structures using a smear-out process.

11. "On the Construction of Models of Continua Interacting with an Electromagnetic Field" by L.I. Sedov and A.G. Tsypkin. For a continuous medium in the presence of interacting material bodies and an electromagnetic field – with allowances for electric currents, polarization, and magnetization -- the authors describe a general theory for constructing a mathematical model. The authors show that the basic variational equation for actual phenomena locally reduces to the first and second laws of thermodynamics.

12. "Special Cases of the Nonlinear Shell Equation" by J.G. Simmonds. The author shows that the inclusion of strain measures and stress-strain relations in the shell equations of motion leads to various forms of nonlinearities. The Von Karman equation is extended to plates undergoing arbitrarily large rotations.

13. "Some Recent Advances in the Application of Nonlinear Elastostatics to Singular Problems" by E. Sternberg. This survey paper outlines two recent studies pertaining to singular problems in the finite equilibrium theory of elastic solids. Such singular problems are the locally unbounded and discontinuous deformation gradients.

The book ends with an interesting lecture by Professor Koiter entitled "Forty Years in Retrospect, the Bitter and the Sweet." It is the story of his scientific struggles and successes over the 40 years of his professional life.

R.A. Ibrahim
Department of Mechanical Engineering
Texas Tech University
Box 4289
Lubbock, TX 79409

VIBRATION IN POWER PLANT PIPING AND EQUIPMENT

R.C. Iotti and M.D. Bernstein, editors
ASME Publ. H00192, New York, NY
1981, 57 pp

As stated by the editors "The object of this symposium is to provide a forum for the exchange of information and to contribute to the state of the art of the design against vibration including its proper assessment." This short volume consists of eight papers packed into 59 pages. The first paper extends previous work on vibration of straight heat exchanger tubes aimed at developing a method for determining the natural frequencies of V-tubes on multiple supports. The second paper reports test results of curved tube arrays in order to assess the effect of flow-induced vibration. The critical flow velocity for onset of fluidelastic instability of a straight tube array can be employed in a conservative sense for a comparable curved tube array. The third paper describes a comprehensive analytical procedure for designing piping systems subjected to vibratory motion. This highly theoretical and mathematical paper is worth studying for its possible influence on piping dynamics.

The fourth paper, although brief, proposes a way to optimize a piping system layout in order to minimize vibration. The fifth paper presents a simple method that the designer can use to modify piping system configurations found to be unacceptable in test or analysis.

The sixth and companion seventh paper are an elaborate treatment of systematic procedures used in acceptance criteria for piping vibration monitoring tests required in nuclear plants. Based upon this analysis, the ASME draft standard is conservative. The companion paper proposes a complete test program that could be performed in an operating nuclear power plant. This program provides a proper perspective of what a good test program should contain.

The final paper analyzes the effects of transient load; in particular, the loss-of-coolant (LOCA). The state of the art is not fully developed in this area. The lack of experimental data and insufficient analytical procedures impose a large cost requirement in terms of computer resources.

In summary, this was a good symposium. It emphasizes deficiencies in understanding transient phenomena and the best way to solve them. The reviewer would have liked more papers on computational efforts and, if possible, computer programs. In addition, the reviewer would have preferred more papers on the dynamic analysis of power plant equipment other than the piping aspect. The reviewer further believes that we have come a long way toward understanding the role of dynamics on power plant design, but there is still a long way to go. We require additional effort to understand the physics and experimentation necessary in the dynamics of power plant design.

H. Saunders
General Electric Company
Building 41, Room 307
Schenectady, NY 12345

SHORT COURSES

APRIL

DESIGN OPTIMIZATION INSTITUTE

Dates: April 11-15, 1983

Place: Tucson, Arizona

Objective: The purpose of this course is to provide engineering designers with an understanding of the optimal design process, exposure to necessary theoretical concepts and to demonstrate application with specific engineering examples. In addition extensive comparative results will be given which will allow a designer to choose a particular code implementation. The course is intended to serve practicing design engineers and is specifically directed toward those who have not had previous training in optimization, but are familiar with the engineering design process.

Contact: Special Professional Education, College of Engineering, Harvill Bldg., Room 237, University of Arizona, Tucson, AZ 85721 - (602) 626-3054.

9TH ANNUAL RELIABILITY TESTING INSTITUTE

Dates: April 18-22, 1983

Place: Tucson, Arizona

Objective: This institute will cover reliability testing concepts, the determination of the failure rate, the distribution of the times-to-failure, and the reliability of components and equipment; the applications of the Weibull distribution to reliability; small sample size, low cost, short duration reliability tests; nonparametric testing; sequential testing; and Bayesian testing.

Contact: Special Professional Education, College of Engineering, Harvill Bldg., Room 237, University of Arizona, Tucson, AZ 87521 - (602) 626-3054.

DYNAMIC BALANCING SEMINAR/WORKSHOP

Dates: April 27-28, 1983

Place: Columbus, Ohio

Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single-, two-, and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions, where each student will be involved in hands-on problem-solving using actual armatures, pump impellers, turbine wheels, etc. with emphasis on reducing costs and improving quality in balancing operations.

Contact: R.E. Ellis, IRD Mechanalysis, Inc., 6150 Huntley Road, Columbus, OH 43229 - (614) 885-5376.

MAY

COMPUTER SIMULATION OF HIGH VELOCITY IMPACT

Dates: May 10-13, 1983

Place: Baltimore, Maryland

Objective: This is an intensive short course dealing with material behavior under short duration loading, numerical methods for impact and penetration problems, a survey of two- and three-dimensional computer codes for impact and penetration studies as well as graphics packages for computational mesh generation and data analysis. Numerous applications involving impact, penetration and material failure under intense, short-duration loading will be presented to illustrate considerations essential for simulation of physical phenomena.

Contact: Dr. J.A. Zukas, Course Coordinator, Computational Mechanics Associates, P.C. Box 11314, Baltimore, MD 21239 - (301) 435-1411.

MULTICRITERION DECISION MAKING: COMPUTER METHODS AND ENGINEERING APPLICATIONS

Dates: May 17-25, 1983

Place: Tucson, Arizona

Objective: This course will demonstrate how to account for the multicriterion nature of decision and management problems in industrial, systems, mining, environmental, and civil engineering. A precise definition of system decision problems will be given and selected techniques presented and illustrated by examples. Real-world case studies and areas of potential applications will be discussed. Workshops will be held using own decision problems and demonstrating computer programs to perform analyses.

Contact: Special Professional Education, College of Engineering, Harvill Bldg., Room 237, University of Arizona, Tucson, AZ 85721 - (602) 626-3054.

ROTOR DYNAMICS

Dates: May 23-27, 1983
Place: Syria, Virginia
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

JUNE

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: June 6-10, 1983
Place: Santa Barbara, California
Dates: August 22-26, 1983
Place: Santa Barbara, California
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 682-7171.

MECHANICS OF HEAVY-DUTY TRUCKS AND TRUCK COMBINATIONS

Dates: June 13-17, 1983
Place: Ann Arbor, Michigan
Objective: This course describes the physics of heavy-truck components in terms of how these components determine the braking, steering, and riding performance of the total vehicle. Covers analytical methods, parameter measurement procedures, and test procedures, useful for performance analysis, prediction and design.

Contact: Continuing Engineering Education, 300 300 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

MACHINERY VIBRATION ANALYSIS

Dates: June 14-17, 1983
Place: Nashville, Tennessee
Dates: Augut 16-19, 1983
Place: New Orleans, Louisiana
Dates: November 15-18, 1983
Place: Chicago, Illinois
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and

equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

VIBRATION DAMPING

Dates: June 19-22, 1983
Place: Dayton, Ohio

Objective: The utilization of the vibration damping properties of viscoelastic materials to reduce structural vibration and noise has become well developed and successfully demonstrated in recent years. The course is intended to give the participant an understanding of the principles of vibration damping necessary for the successful application of this technology. Topics included are: damping fundamentals, damping behavior of materials, response measurements of damped systems, layered damping treatments, tuned dampers, finite element techniques, case histories, and problem solving sessions.

Contact: Michael L. Drake, Kettering Laboratory 104, 300 College Park Avenue, Dayton OH 45469 - (513) 229-2644.

PREVIEWS OF MEETINGS

12TH TRANSDUCER WORKSHOP
June 7-9, 1983
Cocoa Beach, Florida

The 12th Transducer Workshop is scheduled for June 7-9, 1983. The workshop will be held at the Holiday Inn, Melbourne Oceanfront near Cocoa Beach, Florida. A list of the technical presentations is shown below. A tour of the Kennedy Space Center has also been arranged. The final workshop program with registration information and forms will be available the first week of April, 1983.

For additional information contact: William D. Anderson, Chairman, Vehicular Instrumentation/Transducer Committee, TG/RCC, Technical Support Directorate, Naval Air Test Center, Patuxent River, Maryland 20670

TECHNICAL SESSIONS

Session 1: Transducer Systems

- "Measurements on and with Non-linear Systems -- Problems and Approaches," Peter K. Stein, Stein Engineering Services
- "Drift Prediction for a Roll-Stabilized Inertial Measurement System," Vesta I. Bateman, Sandia National Laboratories
- "Performance Evaluation of Sensors," Paul S. Lederer, Wilcoxon Research
- "Test and Evaluation of Radioactively Contaminated Transducers and Transmitters," R.C. Strahm, EG&G Idaho, Inc.
- "Testing Techniques Involved in the Development of High Shock Acceleration Sensors," Bob Sill, Endevco Corporation

Session 2: Temperature, Displacement and Velocity

- "A High Accuracy Temperature Measurement on a Diagnostic Canister for the Nevada Test Site," Donald Gerigh, Lawrence Livermore National Laboratory
- "A New Application of Proximity Probe Measurement on Rolling Element Bearings," Tom McGauvran, Bentley, Nevada
- "Space Shuttle Main Engine Turbopump Transducer," Tom J. Peterson, Rockwell/Rocketdyne
- "Aircraft Displacement Off the Bow," Terry A. Collom, Naval Air Test Center
- "An Angular Velocimeter for Aerospace Applications," Dr. P.W. Whaley, University of Nebraska - Lincoln
- "An Extended Range Penbulous Velocity Gage," Laurence Starrh, Lawrence Livermore National Laboratory and Roger Noyes, EG&G Inc.

Session 3: Pressure

- "Difficulties Encountered in Measuring Small Differential Pressures at High Reference Pressures," Richard T. Hasbrouck, Lawrence Livermore National Laboratory
- "Weapon Chamber Pressure Measurement," W. Scott Walton, U.S. Army Aberdeen Proving Ground

- "Soil Pore Gas Pressure Measurements at the Nevada Test Site," Lee Davies, Roger Noyes, John Kalinowski and Ted Stubbs, EG&G, Inc.

- "Temperature Compensation and Shunt Calibration of Semiconductor Pressure Transducers," Joseph R. Mallon, Jr., Kulite Semiconductor Products, Inc.

- "Applications of the Small Body Pressure Transducer," Robert E. George, Ames Research Center

- "Precise Hydraulically Operated 100,000 lb. Force Transfer Standard," Vern E. Bean and B.E. Welch, National Bureau of Standards

Session 4: Manufacturers Panel

- Eight selected transducer manufacturers will discuss their latest products and answer questions.

Session 5: Vibration and Shock

- "A Systems Approach to Measuring Short Duration Acceleration Transients," Fred Schelby, Sandia National Laboratories

- "Calibration of Vibration Pickups at High Frequencies," B.F. Payne, National Bureau of Standards

- "Shock Isolated Accelerometer," Mark Groethe and Ed Day, S-Cubed

- "High-G Calibration of Accelerometers -- An Evaluation of Methods," Charles Federman and Myroslav R. Serbyn, National Bureau of Standards

- "Aircraft Ground Vibration Test Instrumentation System," David Banaszak and Richard Talmadge, Air Force Wright Aeronautical Laboratories

ABSTRACT CATEGORIES

MECHANICAL SYSTEMS

Rotating Machines
Reciprocating Machines
Power Transmission Systems
Metal Working and Forming
Isolation and Absorption
Electromechanical Systems
Optical Systems
Materials Handling Equipment

STRUCTURAL SYSTEMS

Bridges
Buildings
Towers
Foundations
Underground Structures
Harbors and Dams
Roads and Tracks
Construction Equipment
Pressure Vessels
Power Plants
Off-shore Structures

VEHICLE SYSTEMS

Ground Vehicles
Ships
Aircraft
Missiles and Spacecraft

BIOLOGICAL SYSTEMS

Human
Animal

MECHANICAL COMPONENTS

Absorbers and Isolators
Springs
Tires and Wheels
Blades
Bearings
Belts
Gears
Clutches
Couplings
Fasteners
Linkages
Valves
Seals
Cams

STRUCTURAL COMPONENTS

Strings and Ropes
Cables
Bars and Rods
Beams
Cylinders
Columns
Frames and Arches
Membranes, Films, and Webs
Panels
Plates
Shells
Rings
Pipes and Tubes
Ducts
Building Components

ELECTRIC COMPONENTS

Controls (Switches, Circuit Breakers)
Motors
Generators
Transformers
Relays
Electronic Components

DYNAMIC ENVIRONMENT

Acoustic Excitation
Shock Excitation
Vibration Excitation
Thermal Excitation

MECHANICAL PROPERTIES

Damping
Fatigue
Elasticity and Plasticity

EXPERIMENTATION

Measurement and Analysis
Dynamic Tests
Scaling and Modeling
Diagnostics
Balancing
Monitoring

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Modeling Techniques
Nonlinear Analysis
Numerical Methods
Statistical Methods
Parameter Identification
Mobility/Impedance Methods
Optimization Techniques
Design Techniques
Computer Programs

GENERAL TOPICS

Conference Proceedings
Tutorials and Reviews
Criteria, Standards, and Specifications
Bibliographies
Useful Applications

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of publications abstracted are not available from SVIC or the Vibration Institute, except those generated by either organization. Government Reports (AD-, PB-, or N-numbers) can be obtained from NTIS, Springfield, Virginia 22151; Dissertations (DA-) from University Microfilms, 313 N. Fir St., Ann Arbor, Michigan 48106; U.S. Patents from the Commissioner of Patents, Washington, DC 20231; Chinese publications (CSTA-) in Chinese or English translation from International Information Service Ltd., P.O. Box 24683, ABD Post Office, Hong Kong. In all cases the appropriate code number should be cited. All other inquiries should be directed to libraries. The address of only the first author is listed in the citation. The list of periodicals scanned is published in issues 1, 6, and 12.

ABSTRACT CONTENTS

MECHANICAL SYSTEMS 43

Rotating Machines. 43
Reciprocating Machines . . . 44
Power Transmission Systems. 44
Metal Working and Forming 44

STRUCTURAL SYSTEMS 44

Bridges 44
Buildings 44
Towers 45
Harbors and Dams 45
Roads and Tracks 46
Power Plants. 46
Off-shore Structures. 48

VEHICLE SYSTEMS 49

Ground Vehicles 49
Ships. 50
Aircraft 50
Missiles and Spacecraft 51

BIOLOGICAL SYSTEMS 52

Human 52

MECHANICAL COMPONENTS. 53

Absorbers and Isolators . . . 53
Springs 55
Tires and Wheels 55
Blades. 56
Bearings. 57
Gears 59
Couplings. 59
Linkages 60
Valves. 61

STRUCTURAL COMPONENTS. 61

Strings and Ropes 61
Cables. 61
Bars and Rods. 61
Beams. 62
Frames and Arches 64
Panels 64
Plates 65
Shells 68
Rings 68
Pipes and Tubes 68
Ducts 70
Building Components. 72

DYNAMIC ENVIRONMENT. . . 72

Acoustic Excitation. 72
Shock Excitation. 74
Vibration Excitation 78

MECHANICAL PROPERTIES. . 80

Damping 80
Fatigue 80
Elasticity and Plasticity . . . 81

EXPERIMENTATION 81

Measurement and Analysis. 81
Dynamic Tests 83
Diagnostics. 84

ANALYSIS AND DESIGN 84

Analogs and Analog Computation 84
Analytical Methods 84
Modeling Techniques 86
Numerical Methods 87
Statistical Methods 88
Parameter Identification. . . 89
Design Techniques. 90
Computer Programs. 91

GENERAL TOPICS. 93

Tutorials and Reviews 93
Bibliographies. 93

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see Nos. 489, 491, 558, 622, 656, 659)

83-430
Fractional-Frequency Rotor Motion Due to Nonsymmetric Clearance Effects

D.W. Childs

Texas A&M Univ., College Station, TX 77843, J. Engrg. Power, Trans. ASME, 104 (3), pp 533-541 (July 1982) 9 figs, 8 refs

Key Words: Rotors, Subsynchronous vibration, Whirling, Parametric excitation

Analysis based on the Jeffcott model is presented to explain 1/2 speed and 1/3 speed whirling motion occurring in rotors which are subject to periodic normal-loose or normal-tight radial stiffness variations. The normal-loose stiffness variation results due to bearing-clearance effects, while normal-tight stiffness variations result from rubbing over a portion of a rotor's orbit. A linear parametric-excitation analysis demonstrates that during a normal-tight rubbing condition, Coulomb damping significantly widens the potential range of unstable speeds.

83-431
A Study of the Modal Truncation Error in the Component Mode Analysis of a Dual-Rotor System

D.F. Li and E.J. Gunter

Univ. of Virginia, Charlottesville, VA 22901, J. Engrg. Power, Trans. ASME, 104 (3), pp 525-532 (July 1982) 11 figs, 4 tables, 17 refs

Key Words: Rotors, Modal analysis, Modal truncation, Component mode synthesis

In the component mode synthesis method, the equation of motion in the generalized coordinates is built upon the undamped eigenvalue data of the component structures. Error is inevitable when truncated modes are used. Two model truncation schemes were evaluated with regard to the critical speed, stability, and unbalance response of a two-spool gas turbine engine. The numbers of modes required to yield acceptable accuracy in these cases were determined. Guidelines for modal truncation were derived from these results.

83-432
Component Mode Synthesis of Large Rotor Systems

D.F. Li and E.J. Gunter

Univ. of Virginia, Charlottesville, VA 22901, J. Engrg. Power, Trans. ASME, 104 (3), pp 552-560 (July 1982) 8 figs, 14 refs

Key Words: Rotors, Component mode synthesis, Modal synthesis

A scheme is presented for calculating the vibrations of large multi-component flexible rotor systems based on the component mode synthesis method. It is shown that, by a modal expansion of the elastic interconnecting elements, the system modal equation can be conveniently constructed from the undamped eigen representations of the component subsystems. The capability of the component mode method is demonstrated in two examples: a transient simulation of a two-spool gas turbine engine equipped with a squeeze-film damper; and an unbalance response analysis of the Space Shuttle Main Engine oxygen turbopump in which the dynamics of the rotor and the housing are both considered.

83-433
Vibration Detection of a Transverse Crack in a Rotating Machine Shaft

J.C. Sol

Canada Inst. for Scientific and Tech. Information, Ottawa, Ontario, Canada, Rept. No. ISSN-0077-5606, NRC/CNR-TT-2018, 16 pp (1982)
N82-27763

Key Words: Shafts, Crack detection, Monitoring techniques

The vibrational effects of a crack are reviewed using simple theoretical models, and detection criteria for horizontal axle machines are defined. These criteria are compared with experimental results obtained using a small scale model and from a real machine. Monitoring techniques developed especially to detect defects of this type in turboalternators are presented.

83-434
On the Shaft End Torque and the Unstable Vibrations of an Asymmetrical Shaft Carrying an Asymmetrical Rotor

H. Ota and K. Mizutani

Nagoya Univ., Chikusa-ku, Nagoya, 464, Japan, Bull. JSME, 25 (208), pp 1574-1581 (Oct 1982) 8 figs, 10 refs

Key Words: Shafts, Whirling

In a rotating asymmetrical shaft carrying an asymmetrical rotor, there occur two types of unstable regions. These unstable regions change with the orientation angle ζ between the inequality of shaft stiffness and that of rotor inertia. The conditions under which unstable vibrations occur just as input energy into the rotating shaft system tends to increase the whirling amplitudes of the shaft, can be clearly ascertained.

83-435

An Experimental Study of Rotor-Filter Pump Performance

K.M. Marshek, M.R. Naji, and G.C. Andries

Univ. of Texas at Austin, TX 78712, J. Energy Resources Tech., Trans. ASME, 104 (3), pp 259-268 (Sept 1982) 32 figs, 2 tables, 10 refs

Key Words: Pumps, Pulse excitation

The performance of a rotor-filter pump were studied experimentally. To develop an understanding of pump performance, and in particular to discern the mechanism of hydraulic pulsing, flow visualization in the rotor, vibration analyses of the pump, frequency analysis of the pump hydraulic pressure pulsation, and analyses of flow characteristics for different pick-up tubes in combination with different impellers and cover plates were conducted.

RECIPROCATING MACHINES

(See No. 507)

POWER TRANSMISSION SYSTEMS

(See No. 658)

METAL WORKING AND FORMING

83-436

Dynamic Processes during Contour-Recess Grinding (Dynamische Vorgänge beim Aussenrund-Einstechschleifen)

E. Salje, W. Dietrich, and J. Meyer

VDI Z., 124 (17), pp 623-628 (1982) 16 figs, 3 refs (In German)

Key Words: Grinding, Vibration control

The effect of grinding force and of the volume cut per unit of time on the dynamic processes during grinding is discussed.

STRUCTURAL SYSTEMS

BRIDGES

83-437

Vulnerability of Steel Girder Bridges to Airblast

J.W. Ball and J.P. Balsara

U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 127-135 (Oct 1982) 19 figs, 4 refs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Bridges, Steel, Air blast, Vulnerability, Nuclear weapons effects

Data is provided for the development and verification of an analytical model for vulnerability predictions of a steel girder bridge from airblast of a simulated nuclear detonation. The analytical model represents the bridge span as a rigid body rotating about the edge farthest from ground zero. The differential equation resulting from the conservation of angular momentum is numerically solved.

BUILDINGS

83-438

Earthquake Response of Irregular R/C Structures in the Nonlinear Range

M. Saiidi and K.E. Hodson

Civil Engrg. Dept., Univ. of Nevada, Reno, NV 89557, Computers Struc., 16 (1-4), pp 519-529 (1983) 7 figs, 6 tables, 12 refs

Key Words: Buildings, Reinforced concrete, Seismic response

The application of a simple analytical model (Q-Model) for calculation of nonlinear seismic response history of irregular planar structures is demonstrated. The model represents the structure by an equivalent SDOF oscillator. Stiffness degradation effects are accounted for through a simple hysteresis model. The Q-Model is evaluated for small-scale test structures in addition to a full-scale hypothetical frame.

83-439

Inelastic Response of a Non-Seismically Designed Eleven Story Reinforced Concrete Building

M.R. Button, T.E. Kelly, R.L. Mayes, R. Donikian, and E. Crespo

Computech Engineering Services, Inc., Berkeley, CA 94705, Computers Struc., 16 (1-4), pp 543-548 (1983) 3 figs, 9 refs

Key Words: Buildings, Multistory buildings, Reinforced concrete, Earthquake response, Seismic response

An analytical study is described in which the predicted response of a non-seismically designed eleven story reinforced concrete building subjected to mechanically induced, large amplitude shaking, is correlated with actual inelastic response measured from full scale tests. The best analytical model is then used to predict the response of the structure subjected to earthquake induced ground motion. Conclusions are drawn about the ability of such structures to withstand earthquakes of varying magnitude.

83-440

Noise Induced House Vibrations and Human Perception

H.H. Hubbard

The College of William and Mary, Virginia Associated Res. Campus, 12070 Jefferson Ave., Newport News, VA 23606, Noise Control Engrg., 19 (2), pp 49-55 (Sept/Oct 1982) 12 figs, 32 refs

Key Words: Buildings, Acoustic excitation, Vibration response, Natural frequencies, Mode shapes, Acceleration analysis, Human response

Noise induced house responses including frequencies, mode shapes, acceleration levels and outside-to-inside noise reductions is summarized. The role of house vibrations in reactions to environmental noise is defined and some human perception criteria are reviewed.

TOWERS

(Also see Nos. 544, 545)

83-441

Presentation of Dynamic Design Data Using a Minicomputer

J.S.W. Taylor and I.M. Allison

Univ. of Surrey, Guildford, UK, Engineering Research and Design - Bridging the Gap, Instn. Mech. Engrs. Conf. Publ. 1981-7, pp 9-15, C226/81, 9 figs, 2 refs

Key Words: Towers, Design techniques, Computer-aided techniques, Dynamic response, Lumped parameter method, Graphic methods, Minicomputers

The graphics capability of a minicomputer is used in displaying the deformations of slender towers subjected to dynamic loading. The effect of damping is illustrated using a lumped mass idealization.

HARBORS AND DAMS

(Also see No. 609)

83-442

Hydrodynamic Effect of Earthquakes on Circular Dam-Reservoir Systems

D.S. Kadle and A.T. Chwang

Iowa Inst. of Hydraulic Res., Iowa City, IA, Rept. No. IIHR-246, 74 pp (Aug 1982)

PB82-254137

Key Words: Dams, Earthquake response

This study deals with the hydrodynamic effect of earthquakes on a three-dimensional dam-reservoir system. Analytical solutions in closed forms are obtained when the reservoir is circular or semi-circular in shape. The effects of surface waves and compressibility of the fluid in the reservoir are also included.

ROADS AND TRACKS

(Also see Nos. 487, 488)

83-443

Four Channel Excitation for Simulation of Vertical Road Roughness (Vierkanal-Anregung zur Simulation vertikaler Strassenunebenheiten)

H.-P. Willumeit and M. Lemke

Automobiltech. Z., 84 (10), pp 499-506 (Oct 1982) 12 figs, 2 tables, 24 refs

(In German)

Key Words: Simulation, Road roughness, Noise generation, Vibration excitation

A four-channel, vibration-exciting noise generator for simulation of vertical road roughness is described. The generator produces different stochastic time signals for both tracks, which are correlated by a fixed coherence function. Variable time delays produce the vehicle speed and wheelbase-dependent rear-wheel excitation.

83-444

Analysis of Rigid Pavement on Viscoelastic Foundations Subjected to Moving Loads

S.S. Bandyopadhyay

NFS Services, Inc., Houston, TX, Intl. J. Numer. Anal. Methods Geomech., 6 (4), pp 393-407 (Oct-Dec 1982) 13 figs, 3 refs

Key Words: Roads (pavements), Foundations, Viscoelastic foundations, Moving loads

The dynamic behavior of road structure is analyzed by idealizing the subgrade with different viscoelastic models having three and four elements. Complex Fourier transformation is used to solve the resulting differential equations. The results are presented in non-dimensional form. A detailed study is made to determine the effect of different parameters on the deflection and moment of the pavement. Also, the relative implications of idealizing the subgrade with different viscoelastic models are studied. A numerical example is solved.

POWER PLANTS

83-445

An Approach to Evaluate the Design Load Time History for Normal Engine Impact Taking into Account the Crash-Velocity Distribution

J.D. Riera, N.F. Zorn, and G.I. Schuller

Pôs-Graduacao em Engr. Civil, Escòla de Engenharia - UFRGS, Porto Alegre, Brasil, Nucl. Engrg. Des., 71 (3), pp 311-316 (Aug 11, 1982) 7 figs, 10 refs

Key Words: Nuclear power plants, Crash research (aircraft)

Examination of crash records for military aircraft indicates that in the definition of the excitation due to aircraft impact against nuclear structures, the engines should be considered as independent projectiles and, if necessary, its effects superimposed on those due to the aircraft and/or parts thereof. For the development of reliability based design criteria, it is also necessary to associate different excitation levels to (conditional) probabilities of occurrence. The paper presents a detailed discussion of the characteristics of the reaction-time curve for a Phantom GE J79-8 turbojet engine, together with a procedure to correlate any reaction-time curve to its (conditional) probability of occurrence.

83-446

Seismic Criteria for Older Plants: An Illustration of Decision Analysis

C.A. Cornell

Dept. of Civil Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, Nucl. Engrg. Des., 71 (3), pp 427-429 (Aug 11, 1982) 3 refs

Key Words: Nuclear power plants, Seismic design

It is shown how elementary decision theory can formally quantify the belief that older plants need not be reinforced to the same levels of seismic conservatism used in new plants.

83-447

Estimation of the Time-Dependent Frequency Content of Earthquake Accelerations

R.J. Scherer, J.D. Riera, and G.I. Schüller

Institut f. Bauingenieurwesen III, Technische Universität München, Fed. Rep. Germany, Nucl. Engrg. Des., 71 (3), pp 301-310 (Aug 11, 1982) 9 figs, 8 refs

Key Words: Nuclear power plants, Earthquake response

In order to define seismic random processes, attention is devoted to the evolutionary spectra method. It is shown that the estimation of the evolutionary spectra carried out by the multifilter technique with an approximate consideration of the transient behavior of the filter element may lead to an improved estimator.

83-448

Seismic Risk Analysis and Decisions for Nuclear Power Plants

P.D. Smith
Lawrence Livermore Natl. Lab., P.O. Box 808, L-95 Livermore, CA 94550, Nucl. Engrg. Des., 71 (3), pp 431-432 (Aug 11, 1982) 11 refs

Key Words: Nuclear power plants, Seismic response

This paper briefly describes several categories of safety decisions that can be made using seismic risk analysis. While risk analysis does not provide all the information required for these decisions, it is a useful tool in that it provides additional information for the decision-making process. A growing interest in the use of seismic risk analysis in nuclear safety evaluations is anticipated.

83-449

An Application of System Reliability Analysis for the Study of Reactor Seismic Safety

G.E. Cummings
Univ. of California, Lawrence Livermore Natl. Lab., P.O. Box 808, L-91, Livermore, CA 94550, Nucl. Engrg. Des., 71 (3), pp 341-344 (Aug 11, 1982) 1 fig, 2 tables, 7 refs

Key Words: Nuclear power plants, Seismic response, Damage prediction, Probability theory, Computer programs

Both systems and structural analysis techniques are being employed to calculate failure and radioactive release probabilities in an effort to provide insights into the seismic safety of nuclear power plants. A description is given of an event-tree/fault-tree model of a nuclear power plant which has been constructed and is being used to calculate these probabilities. Failure data for use in this model is generated (in part) from responses calculated by structural analysis codes using earthquake time histories as forcing functions. These responses are applied to fragility functions to determine component and structural failure probability input for the fault trees.

83-450

A Probabilistic Assessment of the Primary Coolant Loop Pipe Fracture Due to Fatigue Crack Growth for a PWR Plant

C.K. Chou
Lawrence Livermore Natl. Lab., Univ. of California, P.O. Box 808, L-90, Livermore, CA 94550, Nucl. Engrg. Des., 71 (3), pp 285-298 (Aug 11, 1982)

Key Words: Nuclear power plants, Earthquake response, Seismic response, Fatigue life

The work reported herein assesses the probability of a double-ended guillotine break of the hot leg, cold leg and cross-over line of a PWR plant subjected to the loads caused by plant transients and earthquakes. Flaw size and aspect ratio, material properties, operating transient and seismic stress histories, pre-service and in-service inspections as well as leak detections are considered random variables to be input into the fatigue crack growth fracture mechanics model. A brief description of the model and interrelationship between various steps are also given.

83-451

Seismic Research on Block-Type HTGR Core

T. Ikushima, T. Honma, and H. Ishizuka
Div. of Nuclear Safety Evaluation, Japan Atomic Energy Res. Inst., Tokai-mura, Naka-gun, Ibaraki-ken, 319-11, Japan, Nucl. Engrg. Des., 71 (2), pp 195-215 (Aug 1, 1982) 40 figs, 2 tables, 9 refs

Key Words: Nuclear reactors, Seismic analysis

This paper describes seismic research conducted by the Japanese Atomic Energy Research Institute in the development of a high-temperature gas-cooled reactor. Descriptions are given of the seismic research program, the seismic tests, and the simulation analyses. Experiments included a two block pendulum collision test and a single stacked block column, a one-region core (seven columns), a two-dimensional vertical core and a two-dimensional horizontal core, vibration tests.

83-452

Aseismic Study of High Temperature Gas-Cooled Reactor Core with Block-type Fuel (2nd Report: An Analytical Method of Two-dimensional Vibration of Interacting Columns)

T. Ikushima

Japan Atomic Energy Research Inst., Tokai-mura, Naka-gun, Ibaraki-ken, 319-11, Japan, Bull. JSME, 25 (208), pp 1610-1617 (Oct 1982) 12 figs, 1 table, 5 refs

Key Words: Nuclear reactors, Seismic design

An analytical method of two-dimensional vibration of interacting columns for aseismic design of a high temperature gas-cooled reactor core with block-type fuel is developed. Blocks are treated as rigid bodies and a spring dashpot model is used for the collision process between blocks. Analytical results are compared with experimental ones and both are found to be in good agreement. The analytical method can be used to predict the behavior of the high temperature gas-cooled reactor core under seismic excitation.

83-453

Dynamic Response of the JT-60 Vacuum Vessel under the Electromagnetic Forces

H. Takatsu, M. Shimizu, M. Ohta, K. Imai, S. Ono, and M. Minami

Japan Atomic Energy Res. Inst., Tokai-mura, Naka-gun, Ibaraki-ken, Japan, Nucl. Engrg. Des., 71 (2), pp 161-172 (Aug 1, 1982) 16 figs, 3 tables, 6 refs

Key Words: Nuclear reactor components, Bellows, Electromagnetic excitation

Dynamic response analyses of the JAERI Tokamak 60 (JT-60) vacuum vessel were carried out under three kinds of saddle-like electromagnetic forces. The dynamic response of the bellows was obtained by dividing it into three components; the first, caused by the forced deflection due to the displacement of an adjacent rigid ring; the second, caused by inertia force; and the third, caused by a saddle-like electromagnetic force. It is clear that the dynamic behavior of the vacuum vessel is governed mainly by the saddle-like electromagnetic force, with a smaller effect of the inverse saddle-like electromagnetic force on the dynamic response of the vacuum vessel.

83-454

Mixed Domain Analysis of Nuclear Containment Structures Using Impulse Functions

S. Ramamurthy and M.J. Shah

Stone & Webster Engrg. Corp., Cherry Hill, NJ 08034, Computers Struc., 16 (1-4), pp 573-579 (1983) 11 figs, 7 refs

Key Words: Nuclear power plants, Containment structures, Time-domain method, Frequency-domain method, Hydrodynamic excitation

An alternative method to analyze containment structures of boiling water reactor (BWR) nuclear plants is proposed. The proposed method reduces the computer cost and provides sufficient accuracy for the analysis of containment structures for hydrodynamic loads, which have a wide spectrum of frequency variation and are of duration in excess of 5 sec. An impulse function time history of duration shorter than the actual forcing function duration is used in time-domain analysis to generate system characteristic functions or transfer functions for a linearly elastic multi degree of freedom structural system. The functions are then used in a frequency-domain analysis along with the Fourier transform of the actual input forcing function time history to obtain the response time histories at various points in the structures.

83-455

Dynamic Response of Containment Vessels to Blast Loading

R.R. Karpp, T.A. Duffey, T.R. Neal, R.H. Warnes, and J.D. Thompson

Los Alamos Natl. Lab., NM, Rept. No. LA-UR-82-344, CONF-820516-5, 7 pp (1982) (Presented at joint conference on experimental mechanics, Honolulu, HI, May 22, 1982)
DE82008123

Key Words: Containment structures, Blast loads, Internal explosions, Explosion effects

The dynamic response of steel, spherical containment vessels loaded by internal explosive blast was studied by experiments, computations, and analysis. Instrumentation used in the experiments consisted of strain and pressure gauges and a velocity interferometer. Data were used to rank the blast wave mitigating properties of several filler materials and to develop a scaling law relating strain, filler material, and explosive energy or explosive mass.

OFF-SHORE STRUCTURES

83-456

Dynamic Analysis Models of Tension Leg Platforms

E.R. Jefferys and M.H. Patel

University College London, London, UK, J. Energy Resources Tech., Trans. ASME, 104 (3), pp 217-223 (Sept 1982) 7 figs, 1 table, 13 refs

Key Words: Drilling platforms, Off-shore structures, Cables, Natural frequencies

Conventional analysis of tension leg platform structures yields natural frequencies which are well separated from wave excitation frequencies. However, the results presented here show that the tethers can have lateral resonant frequencies in the wave frequency range if the platform is deployed in deep water. It is usually assumed that tether tension does not vary with time. However, the vertical wave forces, reacted by the tethers, cause the tension to change with time and this can cause a Mathieu type of instability in the platform sway motion. This phenomenon is investigated using a simple energy balance technique and it is shown that square law fluid damping places an upper bound on oscillation amplitude; it is found that platform sway motions due to Mathieu excitation remain acceptable even in large waves.

83-457

A High-Pressure Swivel for Natural Gas Service and Oscillating Motion in a Marine Environment

J.T. Herbert and J.E. Ortloff

Aeroquip Corp., Jackson, MI, J. Energy Resources Tech., Trans. ASME, 104 (3), pp 229-234 (Sept 1982) 15 figs, 1 table, 12 refs

Key Words: Off-shore structures, Drilling platforms, Marine risers

A joint development program has produced a unique flowline swivel for high-pressure natural gas service under continuous, small degree rotation, oscillating service. The swivel uses an elastomeric bearing element made up of alternate, frusto-conical shaped rings of metal and rubber (elastomer) to absorb continuous small degree rotary oscillations or flexures of the swivel. It accommodates larger oscillations by locking the elastomeric element at its maximum design flexure capability and permitting the entire shaft assembly to rotate relative to the housing.

83-458

Optimum Design and Control of Self-Supported Wave Energy Systems

A. Abuelnaga and A. Seireg

Mech. Engrg. Dept., Univ. of Wisconson, Madison, WI 53706, J. Energy Resources Tech., Trans. ASME, 104 (3), pp 247-256 (Sept 1982) 10 figs, 4 tables, 11 refs

Key Words: Off-shore structures, Floating structures, Moorings, Wave forces, Wave generation

This paper presents a procedure for the design of supporting platforms for wave generators which are essentially self-positioned and require minimum anchoring. The optimum design and control for such systems is given for a selected ocean condition. The study shows that an unanchored platform in an optimally designed two-mass system can provide appropriate support for the wave generator without any significant loss of conversion efficiency.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 475, 654)

83-459

Vehicle Interior Noise Related to External Aerodynamics

R. Buchheim, W. Dobrzynski, H. Mankau, and D. Schwabe

Volkswagenwerk AG, Wolfsburg, West Germany, Intl. J. Vehicle Des., 3 (4), pp 398-410 (Nov 1982) 17 figs, 4 refs

Key Words: Motor vehicle noise, Interior noise, Noise measurement, Wind tunnel testing, Aerodynamic loads

Vehicle interior noise measurements are made in the wind tunnel and on the road. The noise in the passenger compartment of vehicles caused by the external flow around the car is analyzed. Correlations between pressure fluctuations at the outside body surface of a car and the interior noise are established.

83-460

Lateral Running Quality and Stability Design of Railway Carriages

P. Michelberger, A. Simonyi, and M. Ferenczi

Technical Univ. of Budapest, Hungary, Intl. J. Vehicle Des., 3 (4), pp 424-435 (Nov 1982) 7 figs, 6 refs

Key Words: Railroad cars, Lateral response, Stability

One of the current problems of railway car dynamics is the analysis of lateral motions. This paper seeks to determine, by means of a linear model with 14 degrees of freedom, the transfer characteristics of a railway car's wheel-set. The paper describes, through a course of analysis, the elasticity parameters of wheel-set clamping that result in optimal riding comfort. By applying simultaneous differential equations to the model, and with the aid of the Francis double-step algorithm, the stability condition of the model is examined and the set of wheel-set clamping parameters that assure stable running are determined.

83-461

A Review and Assessment of Methods for Prediction of the Dynamic Stability of Air Cushions

P.A. Sullivan, M.J. Hinchey, and G.M. Green
Inst. for Aerospace Studies, Univ. of Toronto, Toronto, Canada, J. Sound Vib., 84 (3), pp 337-358 (Oct 8, 1982) 21 figs, 1 table, 21 refs

Key Words: Ground effect machines, Dynamic stability, Lumped parameter method

The usefulness of lumped-parameter linear stability analyses for the prediction of dynamic instabilities of air cushion vehicles is explored. The configuration considered in detail is a single plenum chamber constrained to move in heave only and which is fed from a fan through a duct. The assumptions and equations typically used in such analyses are discussed and their applicability reviewed. An experiment designed to completely eliminate fan dynamic effects accurately reproduces the predictions of an earlier theoretical analysis of the effect of ducting of cushion stability.

SHIPS

83-462

The Impact Energy of a Moored Tanker under the Action of Regular Waves

Y.-C. Li
Ocean Engrg. Program, Texas A&M Univ., College Station, TX 77843, J. Energy Resources Tech., Trans. ASME, 104 (3), pp 235-240 (Sept 1982) 5 figs, 11 tables, 11 refs

Key Words: Ships, Moorings, Wave forces, Wind-induced excitation

The influence of factors such as mooring line conditions, fender arrangements, dolphin arrangements, degree of ship loading, waves of long period, wave direction, and wind on the impact energy of a moored tanker are studied. Based on systematic test data, a semi-empirical formula is developed to calculate the impact energy of the moored ship on the berthing facilities under the action of regular waves.

AIRCRAFT

(Also see Nos. 445, 578)

83-463

Generation of Desired Signals from Acoustic Drivers

R. Ramakrishnan, M. Salikuddin, and K.K. Ahuja
Lockheed-Georgia Co., Marietta, GA 30063, J. Sound Vib., 85 (1), pp 39-51 (Nov 8, 1982) 9 figs, 18 refs

Key Words: Aircraft noise, Engine noise, Interior noise

A general but systematic procedure is developed to control transient signal generation for the study of internal noise propagation from aircraft engines. Transform techniques are used in a simple algorithm to produce signals of any desired waveform from acoustic drivers. By a judicious input, the accurate driver response function is calculated. From the driver response function the limiting frequency characteristics are determined.

83-464

Exterior Noise on the Fuselage of Light Propeller Driven Aircraft in Flight

J. Sulc, J. Hofr, and L. Benda
Inst. of Thermomechanics, ČSAV, Puškinovo nám. 9, 160 00 Praha 6, Czechoslovakia, J. Sound Vib., 84 (1), pp 105-120 (Sept 8, 1982) 20 figs, 1 table, 15 refs

Key Words: Aircraft noise, Noise measurement

Experimental studies of exterior noise (pressure fluctuations) on the fuselage of twin-engined, propeller driven light commercial aircraft in flight are described. Measurements are made by means of 31 flush mounted special static pressure probes. For the wide range of test conditions, pressure fluctuations depending on propeller rotation and on turbulent fluctuations on the wall are obtained.

83-465

Nonequilibrium Flow over Delta Wings with Detached Shock Waves

R.J. Stalker

Univ. of Queensland, Brisbane, Australia, AIAA J., 20 (12), pp 1633-1639 (Dec 1982) 9 figs, 10 refs

Key Words: Aircraft wings, Shock waves

An analysis is made of the effect of streamwise density changes, due to chemical reactions, on the flow in the shock layer of a medium- to low-aspect-ratio delta wing at angles of incidence such that the shock wave is detached from the leading edges. It is shown that the flow retains the essentially conical character that is associated with the absence of density changes. Near the midspan of the wing, the density changes displace the shock wave toward the wing surface but do not alter the shock shape. The displacement effect predicted by the analysis is confirmed by experiments in a high-enthalpy shock tunnel.

83-466

Longitudinal Control Effectiveness and Entry Dynamics of a Single-Stage-to-Orbit Vehicle

N.X. Vinh and C.F. Lin

Univ. of Michigan, Ann Arbor, MI, Rept. No. NASA-CR-169119, 94 pp (1982)

N82-27351

Key Words: Aircraft, Longitudinal stability, Reentry vehicles

The classical theory of flight dynamics for airplane longitudinal stability and control analysis is extended to the case of a hypervelocity reentry vehicle. This includes the elements inherent in supersonic and hypersonic flight such as the influence of the Mach number on aerodynamic characteristics, and the effect of the reaction control system and aerodynamic controls on the trim condition through a wide range of speed. Phugoid motion and angle of attack oscillation for typical cases of cruising flight, ballistic entry, and glide entry are investigated.

83-467

Harpoon Missile Captive-Carry Dynamic Environments on the A-6E Aircraft

J.A. Zara, R.W. Elton, and J.L. Gubser

McDonnell Douglas Astronautics Co., St. Louis, MO, J. Environ. Sci., 25 (5), pp 15-23 (Sept/Oct 1982) 31 figs, 5 refs

Key Words: Missiles, Weapons systems, Wing stores, Flight tests, Experimental test data, Acoustic measurement, Measurement techniques, Shock response, Vibration measurement

As part of the integration of the U.S. Navy Harpoon Anti-Ship Missile with the A-6 Intruder attack aircraft, flight tests were conducted to measure captive-carry dynamic environments. Catapult launch, arrested landings, and a variety of flight conditions were investigated. Acoustic, shock, and vibration wideband measurements were made at key locations using an instrumented missile. Three flight configurations were flown to assess missile environments at different wing stations and to assess the influence of an adjacent store. Level flight and maneuver conditions were measured covering a wide range of aircraft speeds and altitudes. This paper summarizes the environments measured and discusses the significant characteristics of the data.

MISSILES AND SPACECRAFT

(Also see Nos. 467, 586, 587)

83-468

Evaluation of Component Buildup Methods for Missile Aerodynamic Predictions

S.R. Vukelich and J.E. Jenkins

McDonnell Douglas Astronautics Co., St. Louis, MO, J. Spacecraft Rockets, 19 (6), pp 481-488 (Nov/Dec 1982) 9 figs, 6 tables, 54 refs

Key Words: Missiles, Aerodynamic loads, Prediction techniques

An evaluation of component buildup aerodynamic methods for missile design is presented. The methods presented define the methodology which could be incorporated into a handbook and computer program for missile aerodynamic predictions. Selected criteria and recommended aerodynamic prediction methods for isolated components, interference, inlet/airframe interactions, vortices, and propulsion system effects are presented for use in conceptual or preliminary design. The methods investigated include theoretical, semi-empirical, and empirical techniques presently used in industry.

83-469

Optimum Design of Satellite Antenna Structures Subjected to Random Excitations

V.K. Jha

Ph.D. Thesis, Concordia Univ., Canada (1982)

Key Words: Antennas, Spacecraft antennas, Random excitation, Optimum design, Fatigue life, Natural frequencies, Mode shapes

An overall technique is presented for analysis and optimal design of satellite antenna structures subjected to random excitation of arbitrarily varying profiles of power spectral densities. The design which results in the minimum structural weight yet meets all the design reliability requirements has been considered as the optimum design.

83-470

Aspects of the Dynamics and Controllability of Large Flexible Structures

R.A. Laskin

Ph.D. Thesis, Columbia Univ., 263 pp (1982)

DA8222423

Key Words: Spacecraft, Beams, Equations of motion

This dissertation considers problems of dynamics and control of structural systems characterized by a high degree of flexibility. Structural flexibility typically arises in conjunction with a structure's large physical extent but it need not be confined to such situations. The treatment here emphasizes applications to large flexible spacecraft. Although the approach is somewhat eclectic, the unifying thread is the mutual dependence, in practical problems, between system dynamics and control.

83-471

Response of the STARSAT Satellite to Shock and Retrieval Loadings During the Huron King Test

F.L. DiMaggio, C. Meyer, J. McCormick, M.L. Baron, and I. Sandler

Weidlinger Associates, Consulting Engineers, New York, NY, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 59-64, Oct 1982, 9 figs, 1 table (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1982, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Satellites, Shock tests

A shell structure having a shock mounted STARSAT satellite was subjected to vertical ground shock excitations produced by the underground explosion. In addition, a second loading of the satellite occurred from the requirement of removing the vehicle containing the satellite from the area in which a subsidence crater was expected to form. This paper describes the pre-shot analysis and predictions for the response of the STARSAT satellite to both loadings.

BIOLOGICAL SYSTEMS

HUMAN

(Also see Nos. 440, 610)

83-472

Sleep Disturbance Effects of Traffic Noise -- A Laboratory Study on After Effects

E. Ohrstrom and R. Rylander

Dept. of Environmental Hygiene, Univ. of Gothenburg, Gothenburg, Sweden, J. Sound Vib., 84 (1), pp 87-103 (Sept 8, 1982) 5 figs, 4 tables, 36 refs

Key Words: Traffic noise, Human response

Body movements during sleep and subjective sleep quality, as well as mood and performance were investigated after exposure to intermittent and continuous traffic noise during the night. Compared with intermittent noise, continuous noise had a significantly smaller effect on sleep quality. The results suggest that increased attention should be paid to peak noise levels when standards for nocturnal noise are set.

83-473

Criteria for Acceptable Levels of the Shinkansen Super Express Train Noise and Vibration in Residential Areas

K. Yamanaka, T. Nakagawa, F. Kobayashi, S. Kanada, M. Tanahashi, T. Muramatsu, and S. Yamada

Dept. of Public Health, Nagoya Univ. School of Medicine, 65 Tsuramai-cho Showaku, Nagoya, 466 Japan, J. Sound Vib., 84 (4), pp 573-591 (Oct 22, 1982) 6 figs, 7 tables, 25 refs

Key Words: Traffic noise, Railroad trains, Human response

A survey of residents living along the Shinkansen Railway was conducted by means of a self-administered health questionnaire. Geographically corresponding measurements of noise level and vibration intensity were also taken. The relationship of noise and vibration to positive responses related to bodily symptoms, illness and emotional disturbances was analyzed. This study has produced results indicating that the maximum permissible noise level should not exceed 70 dB(A) in the residential areas.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

83-474

The Broadband Dynamic Vibration Absorber

J.B. Hunt and J.-C. Nissen

Dept. of Mech. Engrg., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 83 (4), pp 573-578 (Aug 22, 1982) 7 figs, 10 refs

Key Words: Dynamic vibration absorption (equipment)

The limited effectiveness of the linear passive dynamic vibration absorber is described. This is followed by an analysis producing the response of a primary system when a nonlinear softening Belleville spring is used in the absorber. It is shown that the suppression bandwidth can be doubled by this means.

83-475

Track Train Dynamics Analysis and Test Program: Locomotive Dynamic Characterization Summary

R.L. Berry

Martin Marietta Aerospace, Denver, CO, Rept. No. NASA-CR-162027, 83 pp (Apr 1982)
N82-28224

Key Words: Suspension systems (vehicles), Interaction: rail-wheel, Locomotives

Locomotive mechanical characteristics, track perturbations, and operational characteristics involving experimentally determined suspension system parameters are analyzed. Suspension bearings, shock absorbers, pads, and two- and three-axle trucks are comparatively evaluated with respect to locomotive design.

83-476

Design Concept of Front Suspension Compliance Application to the Bluebird 910 with Examination of Steering Shimmy

A. Inaba and M. Miyajima

Chassis Test Dept., Nissan Motor Co. Ltd., Yokosuka-shi, Japan, Intl. J. Vehicle Des., 3 (4), pp 411-423 (Nov 1982) 15 figs, 4 refs

Key Words: Suspension systems (vehicles), Design techniques

It is known that the concept of suspension compliance is one of the important parameters in achieving better handling performance and improved riding comfort. Theoretical and experimental analyses were carried out on the influence of the front suspension compliance on steering shimmy and riding comfort. The results of the study were applied to the front suspension design of the Bluebird 910.

83-477

An Experimental Determination of Transfer Impedances for Resilient Mounts

R.T. DeWoody

Ingalls Shipbuilding, Div. of Litton Industries, Pascagoula, MS, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 15-44 (Oct 1982) 70 figs, 10 tables, 10 refs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Mountings, Vibration isolators, Shipboard machinery

Resilient mounts are used in shipboard isolation systems to reduce the structureborne noise transmitted to the hull from machinery. The transfer impedances of resilient mounts are needed to determine the transmitted noise. This study deals with the experimental determination of the transfer impedances for Navy and commercial types of resilient mounts. A mount text fixture was designed and constructed. Force and acceleration data were recorded on the input and output sides of the mount under test.

83-478

A Note on Support Vibrations of a Slider-Crank Mechanism

J.E. Jaskie and D. Kohli

Univ. of Wisconsin, Milwaukee, WI, ASME Paper No. 82-DET-76

Key Words: Supports, Slider crank mechanisms

This paper derives the equations of motion through Euler-Lagrangian formulation for the case of a slider-crank mechanism on flexible supports. These nonlinear equations were also approximated by using the truncated Taylor series approximation about the rigid body motion.

83-479

A Guide to Selecting Powertrain Isolators

R. Racca, Sr.

Barry Controls, Automotive Engineering (SAE) 90 (11), pp 68-74 (Nov 1982) 8 figs (Based on SAE Paper No. 821095)

Key Words: Isolators, Vibration isolators, Motor vehicle engines, Driveline vibration

The factors involved in the selection of powertrain isolators are discussed. The article deals with preliminary design factors and describes mounting requirements. Isolator selection requirements are also enumerated.

83-480

Optimal Vibration Reduction over a Frequency Range

W.D. Pilkey, L. Kitis, and B.P. Wang

Dept. of Mech. and Aerospace Engrg., Univ. of Virginia, Charlottesville, VA 22901, Shock Vib. Dig., 14 (11), pp 19-27 (Nov 1982) 9 figs, 28 refs

Key Words: Vibration absorption (equipment), Vibration control, Harmonic excitation, Reviews

This is a review of optimal vibration reduction techniques for systems subject to harmonic excitation over a frequency range. Only passive means of control are considered. The objective functions used for optimization are restricted to those that relate directly to some measure of frequency response. Other common optimization goals such as weight minimization with response constraints are not included in this survey.

83-481

Preliminary Sizing of Vibration Absorber for Space Mast Structures

M.F. Card, H.G. McComb, Jr., and S.W. Peebles

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-84488, 31 pp (May 1982)

N82-28346

Key Words: Vibration absorption (equipment), Antennas, Spacecraft antennas

A simple method of sizing a vibration absorber for a large, cantilevered flexible mast is presented. The method is based on Den Hartog's vibration absorber theory for two-degree-of-freedom systems. Generalized design curves are presented as well as specific numerical results for a candidate space experiment in which a long flexible antenna mast is attached to the shuttle orbiter and dynamically excited by orbiter accelerations.

83-482

Analysis and Design of Two Degree-of-Freedom Vibration Absorber for Reducing the Three Dimensional X, Y, θ Resonances

Y. Okada, M. Kurata, and H.J. Yang

Ibaraki Univ., Hitachi, Japan, ASME Paper No. 82-DET-104

Key Words: Dynamic vibration absorption (equipment), Vibration absorption (equipment), Modal damping

One of the effective means of increasing modal damping is by the use of dynamic vibration absorbers. However, mismatching will result in a severe deterioration in performance. This paper introduces a two degree-of-freedom vibration damper which has two damper masses coupled serially to the main structure. Analyzing the various damper parameters, two design methods were calculated: the first determines the auxiliary system parameters so that the main structure has the lowest peak resonances; the other is based on the philosophy that a damper's performance should be less sensitive to parameter changes.

83-483

Isolating Shock and Vibration

C. Gilbert and H. LeKuch

Aeroflex Laboratories, Inc., Plainview, NY, Mech. Engrg., 104 (10), pp 58-63 (Oct 1982) 5 figs

Key Words: Isolators, Shock isolators, Vibration isolators, Elastomers, Helical springs

A guide for selecting isolators for electronic systems, instrumentation, and other sensitive equipment, particularly under severe service conditions, is presented. A typical vibration or shock isolator consists of a resilient element generally housed in a metallic supporting frame. Among the resilient elements, the serious contenders for severe service applications are elastomers and wire rope, sometimes called helical cable mounts. The characteristics of isolators with these two types of resilient elements are discussed.

83-484
Performance of Different Kinds of Dual Phase Damping Shock Mounts
R.R. Guntur and S. Sankar
Dept. of Mech. Engrg., Union College, Schenectady, NY, J. Sound Vib., 84 (2), pp 253-267 (Sept 22, 1982) 15 figs, 5 tables, 7 refs

Key Words: Shock isolators, Dampers, Design techniques

A detailed performance analysis of six different kinds of dual phase damping shock mounts is presented. The conclusions of this study are of interest to engineers concerned with the design of shock mounts. The results also contain important clues which may be useful in guiding future research workers in the development of a theory of the optimization of nonlinear damping.

83-485
MX-MPS Launcher Shock Isolation System Development
A.A. Rosener
Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 65-94 (Oct 1982) 37 figs, 6 tables (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Shock isolators, Protective shelters, Missile launchers

A detailed description of the MX multiple protective structure launcher shock isolation system development is provided. Included is the process of selecting the type of liquid spring/damper design based on the nuclear weapon environment and preset design drivers. This includes missile allowables, protective structure allowable rattle space, and launcher size. The design of the system is provided and the conceptual design hardware is described.

83-486
Passive Pneumatic Shock Isolator: Analysis and Design
M.S. Hundal
Dept. of Mech. Engrg., Univ. of Vermont, Burlington, VT 05405, J. Sound Vib., 84 (1), pp 1-9 (Sept 8, 1982) 7 figs, 8 refs

Key Words: Shock isolators, Pneumatic isolators, Pneumatic dampers

The analysis of response of a pneumatic shock isolator to base acceleration of rectangular and half-sine shape is described. The isolator consists of a pneumatic damper in parallel with a linear spring. The equations of motion are cast into nondimensional form by defining dimensionless parameters corresponding to mass, stiffness and area. Steps for optimum system design are given.

SPRINGS

(See No. 646)

TIRES AND WHEELS

83-487
Evaluation of a Simulated Road Texture for the Testing of Tire/Road Noise
E. Stusnick and K.J. Plotkin
Wyle Labs., Wyle Res., Arlington, VA, Rept. No. WR-82-3, EPA-550/9-82-332, 84 pp (Mar 1982) PB82-250127

Key Words: Interaction: tire-pavement, Noise generation, Test facilities

As part of a project to study tire/road noise, a laboratory roadwheel facility was equipped with replica road surfaces. To evaluate the effect of pavement texture, and to establish the realism of the replica surfaces, a series of near-field measurements of noise from four heavy truck tires were made on the replica surfaces and on moving tests on the real surfaces.

83-488
A Unified Set of Models for Tire/Road Noise Generation
K.J. Plotkin and E. Stusnick
Wyle Labs./Wyle Research, Arlington, VA, Rept. No.

WR-81-26, EPA-550/9-82-345, 63 pp (July 1981) PB82-250150

Key Words: Interaction: tire-pavement, Noise generation

A set of theoretical models has been prepared which describes the noise generated by tire/road interaction. The mechanisms considered are air pumping and carcass vibration.

BLADES

(Also see No. 656)

83-489

The Influence of Blade Number Ratio and Blade Row Spacing on Axial-Flow Compressor Stator Blade Dynamic Load and Stage Sound Pressure Level

H.E. Gallus, H. Grollius, and J. Lambertz

Inst. for Jet Propulsion and Turbomachines, Technical Univ. Aachen, W. Germany, J. Engrg. Power, Trans. ASME, 104 (3), pp 633-641 (July 1982) 20 figs, 14 refs

Key Words: Blades, Turbomachinery, Compressors, Interaction: rotor-stator, Sound pressure levels

In axial-flow turbomachines considerable dynamic blade loads and noise production occur as a result of the unsteady blade row interaction between rotor and stator blades. This paper presents results of midspan measurements of the dynamic pressure distribution on the stator blade surface (fixed number of blades) for various rotor-blade numbers and various axial clearances between rotor and stator.

83-490

The Effect of Bending-Torsion Coupling on Fan and Compressor Blade Flutter

O.O. Bendiksen and P.P. Friedmann

Dept. of Aerospace Engrg., Univ. of Southern California, Los Angeles, CA 90007, J. Engrg. Power, Trans. ASME, 104 (3), pp 617-623 (July 1982) 13 figs, 26 refs

Key Words: Blades, Fan blades, Compressor blades, Turbomachinery blades, Flutter, Coupled response, Flexural vibration, Torsional vibration

A study of the effects of bending-torsion interaction of the flutter boundaries of turbomachinery blading is presented. The blades are modeled as equivalent sections, and the equations of motion allow for the general case of structural, inertial and aerodynamic coupling, in the presence of structural damping. Two different speed regimes are investigated: incompressible flow, and supersonic flow with a subsonic leading edge locus. Flutter boundaries are presented for cascade design parameters representative of current technology fan rotors.

83-491

Supersonic Stall Flutter of High-Speed Fans

J.J. Adamczyk, W. Stevans, and R. Jutras

NASA Lewis Res. Ctr., Cleveland, OH 44135, J. Engrg. Power, Trans. ASME, 104 (3), pp 675-682 (July 1982) 11 figs, 11 refs

Key Words: Blades, Fans, Flutter, Compressors

An analytical model is developed for predicting the onset of supersonic stall bending flutter in axial-flow compressors. The analysis is based on a modified two-dimensional, compressible, unsteady actuator disk theory. It is applied to a rotor blade row by considering a cascade of airfoils whose geometry and dynamic response coincide with those of a rotor blade element at 85 percent of the span height (measured from the hub).

83-492

Non-Linear Flapping Vibrations of Rotating Blades

C. Venkatesan and V.T. Nagaraj

Dept. of Aeronautics, Indian Inst. of Science, Bangalore-560012, India, J. Sound Vib., 84 (4), pp 549-556 (Oct 22, 1982) 2 figs, 17 refs

Key Words: Blades, Propeller blades, Natural frequencies

The nonlinear equations of motion of a rotating blade undergoing extensional and flapwise bending vibrations are derived. The strain-displacement relationship derived is compared with expressions derived by earlier investigators and the errors and the approximations made in some of those are brought out. The equations of motion are solved under the inextensionality condition to obtain the influence of the amplitude on the fundamental flapwise natural frequency of the rotating blade.

83-493
Application of the Reissner Method to Derive the Coupled Bending-Torsion Equations of Dynamic Motion of Rotating Pretwisted Cantilever Blading with Allowance for Shear Deflection, Rotary Inertia, Warping and Thermal Effects

K.B. Subrahmanyam, S.V. Kulkarni, and J.S. Rao
Dept. of Mech. Engrg., NBKR Inst. of Science and Tech., Vidyanagar -- 524 413, India, J. Sound Vib., 84 (2), pp 223-240 (Sept 22, 1982) 2 figs, 3 tables, 37 refs

Key Words: Blades, Coupled response, Flexural vibration, Torsional vibration, Transverse shear deformation effects, Rotary inertia effects, Warping, Temperature effects, Reissner method

The dynamic Reissner functional in conjunction with variational calculus has been employed to derive the equations of motion of pretwisted cantilever blades of asymmetric aerofoil cross section. Shear deflection, rotary inertia, warping, thermal and rotational effects are considered, with the blade assumed to be mounted on a rotating disc at a stagger angle. It is observed that the thermal bending and twisting moments form an implicit set of additional terms in the respective conventional equations and further that these equations appear to be unwieldy when pretwist is present.

BEARINGS
(Also see Nos. 620, 660)

83-494
Flange Loads Measurements in a Cylindrical Roller Bearing

T.A. Dow and J.W. Kannel
Battelle, Columbus Laboratories, Columbus, OH 43201, J. Lubric. Tech., Trans. ASME, 104 (3), pp 321-326 (July 1982) 12 figs, 12 refs

Key Words: Bearings, Cylindrical bearings, Turbine components

A method of measuring the forces between a roller and the guide flange in a turbine main shaft bearing has been developed. Experimental measurements of these forces were made for a nonpreloaded bearing with nominally balanced rollers and also intentionally unbalanced rollers. The bearing was radially loaded and measurements of the flange forces were made with the rollers, both in and out of the loaded region. Two different lubricants were studied, and significantly different flange forces were measured as a result of the change in viscosity.

83-495
Effect of Grain Flow Orientation on Rolling Contact Fatigue Life of AISI M-50

A.H. Nahm
Aircraft Engine Business Group, General Electric Co., Cincinnati, OH 45215, J. Lubric. Tech., Trans. ASME, 104 (3), pp 330-335 (July 1982) 8 figs, 7 refs

Key Words: Bearings, Rolling contact bearings, Fatigue life

Accelerated rolling contact fatigue tests were conducted to study the effect of grain flow orientation on the rolling contact fatigue life of vacuum induction melted and vacuum arc remelted AISI M-50. Cylindrical test bars were prepared from a billet with 0, 45, and 90 deg orientations relative to billet forging flow direction. It was observed that rolling contact fatigue life increased when grain flow line direction became more parallel to the rolling contact surface.

83-496
A Unified Model for Rolling Contact Life Prediction

T.E. Tallian
SKF Industries, Inc., King of Prussia, PA 19406, J. Lubric. Tech., Trans. ASME, 104 (3), pp 336-346 (July 1982) 3 figs, 17 refs

Key Words: Bearings, Rolling contact bearings, Fatigue life

Systematizing a ten-year development of engineering models for the prediction of rolling contact fatigue life distributions, a unified model is presented. Based on a crack growth rate relationship with local plastic strain and ductility, and on defect populations in the contact material and at the contact surfaces, the model predicts life of a defect, then generalizes to rolling body life. Subsurface and surface failure modes are considered; the effects of material matrix, defect severity, stress condition, surface traction, and asperity interactions are encompassed.

83-497
An Investigation of Free Rolling Resistance at Light Loads

P.H. Markho
Dept. of Mech., Marine and Production Engrg., Liverpool Polytechnic, UK, J. Lubric. Tech., Trans. ASME, 104 (3), pp 376-381 (July 1982) 5 figs, 23 refs

Key Words: Balls, Ball bearings, Rolling friction

This paper presents the results of an investigation into the resistance to free rolling, under light loads, of a ball bearing

ball on a flat track of unhardened En 31 steel using a pendulum arrangement in partial vacuum (5-50 Pa). The effect of air resistance (from experiments conducted in air) is demonstrated and results of tests at different frequencies and loads are presented. These include estimates of the effective hysteresis loss factor and of the coefficient of rolling resistance.

83-498

Roller Skewing Behavior in Roller Bearings

L.J. Nypan

California State Univ., Northridge, CA 91330, J. Lubric. Tech., Trans. ASME, 104 (3), pp 311-320 (July 1982) 7 figs, 9 refs

Key Words: Bearings, Roller bearings, Alignment

Measurements of roller skewing of a 1.15 length to diameter ratio roller in 118 mm bore roller bearings of 0.18 and 0.21 mm (0.0073 and 0.0083 in.) clearance operating with a 4450 N (1000 lb) radial load at shaft speeds of 4000, 8000, and 12,000 rpm with outer race misalignment of 0, 0.5, and −0.5 deg are reported.

83-499

Effects of Ultra-Clean and Centrifugal Filtration on Rolling-Element Bearing Life

S.H. Loewenthal, D.W. Moyer, and W.M. Needelman

NASA Lewis Res. Ctr., Cleveland, OH 44135, J. Lubric. Tech., Trans. ASME, 104 (3), pp 283-292 (July 1982) 5 figs, 6 tables, 20 refs

Key Words: Bearings, Rolling contact bearings, Ball bearings, Lubrication, Fatigue tests

Fatigue tests were conducted on groups of 65-millimeter bore diameter deep-groove ball bearings in a MIL-L-23699 lubricant under two levels of filtration. These tests were intended to determine the upper limit in bearing life under the strictest possible lubricant cleanliness conditions.

83-500

Inclusions and Service Induced Cracks in a Mature Population of Gas Turbine Engine Bearings

J.R. Barton, F.N. Kusenberger, and B.B. Baber

Southwest Res. Inst., San Antonio, TX 78284, J. Lubric. Tech., Trans. ASME, 104 (3), pp 300-310 (July 1982) 11 figs, 3 tables, 34 refs

Key Words: Bearings, Rolling contact bearings, Fatigue life

Comprehensive NDE data have been acquired on approximately 1000 main shaft ball bearings used in J57/TF33 gas turbine engines by processing through the Automated Bearing Inspection System, Mark I CIBLE. Bearing service hours ranged from zero (new) to approximately 13,000 hr; inclusions and service induced cracks were detected in a significant number of components. Endurance testing as well as metallurgical sectioning and scanning electron microscope investigations were used in correlation analyses.

83-501

An Analysis of Dynamic Characteristics of Turbulent Journal Bearings Considering Inertia Forces

H. Hashimoto and S. Wada

Tokai Univ., Hiratsuka-shi-Kanagawa, Japan, Bull. JSME, 25 (208), pp 1601-1609 (Oct 1982) 7 figs, 8 refs

Key Words: Bearings, Journal bearings, Fluid-film bearings, Inertial forces, Spring constants, Damping coefficients

A means of handling both turbulent and inertia effects on the dynamic characteristics of finite width journal bearings is presented. In the analysis turbulence is treated by means of turbulent coefficients and inertia forces are approximated by mean velocities averaged across the fluid film. Assuming a small displacement of journal center, the dynamic coefficients such as spring, damping and acceleration coefficients and the onset whirl frequencies of rotors are computed.

83-502

Optimum Design of Squeeze-Film Damper Bearings

R.A. Cookson and S.S. Kossa

School of Mech. Engrg., Cranfield Inst. of Tech., UK, Engineering Research and Design - Bridging the Gap, Instn. Mech. Engrs. Conf. Publ. 1981-7, pp 31-37, C229/81, 6 figs, 2 tables, 14 refs

Key Words: Bearings, Squeeze-film dampers, Optimum design

A program of research into the operation of the squeeze-film damper bearing and its effectiveness has indicated that optimum effectiveness of the device can be achieved for certain combinations of the bearing parameters. Some of these research findings are included in this paper, together with the recommended design parameters which have developed from this work. It should now be possible for the designer of a squeeze-film damper bearing to achieve a significant degree of vibration attenuation by ensuring that the properties of his damper conform to the recommended values.

83-503

Clarification of Lubricant Frothing and the Determination of the Mean Filling Ratio in Plain Bearings Subjected to Dynamic Loads (Beitrag zur Klärung der Schmierstoffverschäumung sowie der Fullungsgradermittlung in dynamisch belasteten Gleitlagern)

H. Peeken and A. Kohler

VDI Z., 124 (20), pp 783-789 (1982) 17 figs, 11 refs

Key Words: Bearings, Plain bearings, Lubrication

This article elucidates the influence of frothing on the gap filling conditions in a plain bearing that is subjected to dynamic loads and also states a procedure by which it is possible to determine lubricating gap areas of a short plain bearing that are incompletely filled with an incompressible liquid.

83-504

Analytical and Experimental Investigation of Magnetic Support Systems. Part 1: Analysis

J.A. Walowit and O. Pinkus

Mechanical Technology Inc., 968 Albany-Shaker Rd., Latham, NY 12110, J. Lubric. Tech., Trans. ASME, 104 (3), pp 418-428 (July 1982) 19 figs, 6 refs

Key Words: Magnetic bearings, Magnetic suspension techniques

Analytical and experimental studies on the fundamental relationships governing the forces in an axially active, transversely passive electro-magnetic support system are reported. By the use of some simplifying assumptions regarding the boundary conditions, solutions are obtained by means of a Schwarz-Christoffel transformation, which provides the field forces as a function of the relevant geometric and magnetic parameters. The existence of optimum geometric configurations for stiffness and tangential force per given surface area is established and the analysis provides criteria for determining these configurations.

83-505

Analytical and Experimental Investigation of Magnetic Support Systems. Part II: Experimental Investigation

P.R. Albrecht, J. Walowit, and O. Pinkus

Mechanical Technology, Inc., 968 Albany-Shaker Rd., Latham, NY 12110, J. Lubric. Tech., Trans. ASME, 104 (3), pp 429-437 (July 1982) 17 figs, 1 ref

Key Words: Magnetic bearings, Magnetic suspension techniques

An experimental apparatus was developed for measuring forces and fluxes in the gap between magnetic surfaces. A test program, conducted for both aligned and misaligned teeth, showed very good agreement between the analytical expressions developed in a companion paper and the present test results. This agreement was found to prevail even at relatively high flux levels and a high degree of misalignment.

GEARS

83-506

Dynamic Behaviour of Geared Systems with Backlash Due to Stick-Slip Vibratory Motion

D. Michalopoulos and A. Dimarogonas

School of Engrg., Univ. of Patras, Patras, Greece, Wear, 81, pp 135-143 (1982) 6 figs, 11 refs

Key Words: Gears, Stick-slip response, Backlash effects

Stick-slip phenomena occur with low speed rotors in fluid bearings. A typical case is the turning gear mechanism of large turbomachinery which becomes vulnerable to damage. In other cases such as rolling mills or textile machinery the stick-slip phenomenon influences product quality. An analytical investigation of a linear rotor with a complex turning gear system of many degrees of freedom is presented. Gearing backlash was included in the model. The mechanism of backlash was found to be of considerable importance for the appearance of instability. Velocity and damping were the most influential factors on the amplitude of stick-slip motion and instability.

COUPLINGS

83-507

The Torsional Effects of Using Heavy Fuels in Diesel Power Systems

R.J. Hagler and B.W. Hoffman

American Vulkan Corp., P.O. Drawer 673, Winter Haven, FL 33880, Proc. Natl. Conf. on Power Transmission, 9th Annual Mtg., Houston, TX, Nov 16-18, 1982, pp 233-235, 4 figs

Key Words: Couplings, Torsional vibration, Diesel engines, Lubrication

Diesel engine manufacturers, as well as operators of the equipment, have been concentrating on reducing operating costs by reducing rotating weight, higher horsepower output per cylinder and using lower grade fuels. These changes have resulted in changing the method of approaching the torsional calculation from the view of a perfect system, uniform output per cylinder, to the condition where one cylinder has no fuel injected into the chamber (misfire) but the cylinder still compresses the gas. The results of these calculations and their effects on coupling selection are discussed and compared with field measurements.

83-508

Lateral Vibration Considerations in Coupling Selection

R.L. Eshleman and H. Schwerdlin

Vibration Institute, Clarendon Hills, IL, Proc. Natl. Conf. on Power Transmission, 9th Annual Mtg., Houston, TX, Nov 16-18, 1982, pp 225-231, 8 figs, 3 tables, 4 refs

Key Words: Couplings, Natural frequencies, Lateral vibration, Coupled systems

Techniques for obtaining lateral natural frequencies of coupled mechanical systems are discussed. The effect of coupling selection on lateral frequencies is considered in mathematical models of mechanical systems. Tests to obtain physical data are discussed along with the formulae to calculate natural frequencies. The techniques are applied to a motor blower system.

LINKAGES

83-509

Computer-Aided Dynamic Force, Stress, and Gross-Motion Response Analyses of Planar Mechanisms Using Finite Line Element Technique

C. Baggi and J. Abounassif

Tennessee Technological Univ., Cookeville, TN, ASME Paper No. 82-DET-11

Key Words: Mechanisms, Finite element technique, Computer-aided technique

Automated computer technique using planar irregular line element is developed for dynamic force, torque, stress, and deflection analysis of single degree of freedom planar mechanisms. A mechanism can have any number of links, any shape of links, and any type of planar kinematic pair, and may be subjected to externally applied and inertial forces and moments.

83-510

Dynamic Instability of the Elastic Coupler of a Four-Bar Mechanism

M.C. Constantinou and I.G. Tadjbakhsh

Rensselaer Polytechnic Inst., Troy, NY, ASME Paper No. 82-DET-6

Key Words: Four bar mechanisms, Dynamic stability

The dynamic stability of a four-bar mechanism is investigated. Regions of instability are given for a variety of the geometry parameters of the mechanism. Deflections of the first mode of the coupler are calculated. Consideration of higher modes is shown to be of negligible influence.

83-511

A Note on the Effect of Foundation Motion Upon the Response of Flexible Linkages

C.K. Sung and B.S. Thompson

Wayne State Univ., Detroit, MI, ASME Paper No. 82-DET-26

Key Words: Linkages, Vibrating foundations

The classical assumptions employed in the design of linkages are that these mechanisms comprise an assemblage of rigid bodies located on a stationary foundation. The limitations of this statement are examined by modeling flexible planar linkages on foundations vibrating in the plane of the mechanism. The elastic coupler and rocker links are assumed to deform principally in flexure in the plane of the mechanism and the foundation motion is taken to be purely sinusoidal.

83-512

Generation of Elastic Stress Waves at a Corner Junction of Square Rods

K.H. Yong and K.J. Atkins

Gang-Nail Australia Limited, Singapore, J. Sound Vib., 84 (3), pp 431-441 (Oct 8, 1982) 6 figs, 11 refs

Key Words: Rods, Joints (junctions), Wave propagation, Elastic waves, Pulse excitation

Fourier techniques are used to predict the transmitted and reflected waves at an L-joint in rods of square cross-section. The expressions for both longitudinal and flexural wave components are derived for a variable angle of connection for the rods. These components are evaluated for a 90° angle of connection and an arbitrary longitudinal input pulse. The predicted waves are compared with experimental results at a number of locations away from the joint for an input pulse with wavelengths which are large compared with the cross-sectional dimensions of the rods. Good agreement is obtained for all waves.

VALVES

(See No. 548)

STRUCTURAL COMPONENTS

STRINGS AND ROPES

83-513

On the Dynamics of Constrained Multibody Systems

J.W. Kamman

Ph.D. Thesis, Univ. of Cincinnati, 183 pp (1982) DA 8223050

Key Words: Chains, Computer programs

The governing equations for constrained multibody systems are formulated in a manner suitable for their automated, numerical development and solution. Specifically, the closed loop problem of multibody chain systems is addressed. The governing equations are developed by modifying dynamical equations obtained from Lagrange's form of d'Alembert's principle. This modification, which is based upon a solution of the constraint equations through a zero eigenvalues theorem, is in effect a contraction of the dynamical equations.

83-514

Kinematic, Static and Dynamic Investigations of a Plane Single-Loop Kinematic Chain with Prismatic Joints

Y.I. Yankov

Higher Inst. for Mining and Geological Engrg., Sofia 1156, Bulgaria, Mech. Mach. Theory, 17 (5), pp 313-319 (1982) 6 figs, 6 refs

Key Words: Chains

A plane single-loop closed kinematic chain with prismatic joints and many degrees of freedom is studied. Some formulas expressing the displacement, the velocities and the accelerations of an arbitrary order of the links by means of generalized coordinates; i.e., the distances between the sliders of the adjacent links, and their derivatives respectively are obtained making use of the intrinsic transmission functions. The equations connecting the effective forces applied to every two adjacent links are derived for the state of equilibrium of the kinematic chain by applying the principle of virtual work. The differential equations for the movement of the kinematic chain are obtained.

CABLES

(Also see No. 456)

83-515

Modal Stiffnesses of a Pretensioned Cable Net

C.R. Calladine

Dept. of Engrg., Univ. of Cambridge, Cambridge CB2 1PZ, UK, Intl. J. Solids Struc., 18 (10), pp 829-846 (1982) 8 figs, 8 refs

Key Words: Cables, Modal analysis, Stiffness coefficients

This paper is concerned with the structural mechanics of pretensioned saddle-shaped cable nets. Such nets are normally regarded as being nonlinear systems; but it is shown that their behavior may be described satisfactorily in terms of two distinct, and practically independent, sets of extensional and inextensional modes. Each set of modes may be studied by means of suitable linear analysis, and the eigenmodes may be found without difficulty.

BARS AND RODS

(Also see No. 512)

83-516

Vibrations of Vertical Rods with an Attached Mass

H. Saito, S. Chonan, and T. Kobari

Dept. of Mech. Engrg., Tohoku Univ., Sendai, Japan, J. Sound Vib., 84 (4), pp 519-527 (Oct 22, 1982) 8 figs, 3 refs

Key Words: Rods, Mass-beam systems, Natural frequencies, Timoshenko theory

Free flexural vibrations of vertical rods having an attached mass at an intermediate point and different end constraints are investigated, with consideration of the axial force owing to the weight of a mass. The frequency equation is derived on the basis of Timoshenko beam theory. The first and second natural frequencies are obtained numerically and compared with those of rods which have no axial force due to gravity.

BEAMS

(Also see Nos. 470, 481, 648, 657)

83-517

Natural Frequencies for Out-of-Plane Vibrations of Curved Beams on Elastic Foundations

T.M. Wang and W.F. Brannen

Dept. of Civil Engrg., Univ. of New Hampshire, Durham, NH 03824, J. Sound Vib., 84 (2), pp 241-246 (Sept 22, 1982) 2 figs, 12 refs

Key Words: Beams, Curved beams, Elastic foundations, Natural frequencies

A study of the natural out-of-plane vibrations of circular curved beams on elastic foundations is presented. The frequency equation is derived for a clamped-clamped beam and numerical results are given to show the effects of the opening angle of the curved beam and foundation constants on the natural frequencies of the beam.

83-518

Vibration of a Cantilever Beam with a Base Excitation and Tip Mass

C.W.S. To

Dept. of Mech. Engrg., Univ. of Calgary, Calgary, Alberta, Canada T2N 1N4, J. Sound Vib., 83 (4), pp 445-460 (Aug 22, 1982) 2 figs, 1 table, 10 refs

Key Words: Beams, Cantilever beams, Mass-beam systems, Base excitation, Natural frequencies, Mode shapes

Methods are described for calculation of natural frequencies and mode shapes of a cantilever beam with a base excitation and tip mass whose center of gravity does not coincide with the point of attachment. Exact expressions for natural frequencies and mode shapes are derived. Some typical results are presented.

83-519

An Investigation of the Beam Impact Problem

G. Hughes and D.M. Speirs

Cement and Concrete Association, Slough, UK, Rept. No. TR-546, ISBN-0-7210-1246-9, 120 pp (1982) PB82-251174

Key Words: Beams, Reinforced concrete, Impact response, Impact tests

This report describes 80 impact tests on pin-ended reinforced concrete beams and 12 tests on simply supported reinforced concrete beams. For each test, the impact force history and beam displacements were measured. Various models of the impact are discussed.

83-520

Beam Bending-Torsion Dynamic Stiffness Method for Calculation of Exact Vibration Modes

W.L. Hallauer, Jr. and R.Y.L. Liu

Dept. of Aerospace and Ocean Engrg., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 85 (1), pp 105-113 (Nov 8, 1982) 3 figs, 1 table, 19 refs

Key Words: Beams, Dynamic stiffness, Matrix methods, Natural frequencies, Mode shapes, Coupled response, Torsional response, Flexural response

The exact dynamic stiffness matrix is derived for a straight and uniform beam element whose elastic and inertial axes are not coincident. Elementary bending-torsion beam theory is used, and bending translation is restricted to one direction. The element matrix can be used in the dynamic stiffness method for calculation of exact natural frequencies, mode shapes, and generalized masses for planar assemblages of connected bending-torsion beams. The dynamic stiffness method is outlined, and details pertinent to the bending-torsion beam element are given.

83-521
On the Two Frequency Spectra of Timoshenko Beams
M. Levinson and D.W. Cooke
Dept. of Mech. Engrg., Univ. of Maine at Orono, Orono, ME 04469, J. Sound Vib., 84 (3), pp 319-326 (Oct 8, 1982) 1 table, 15 refs

Key Words: Beams, Timoshenko theory, Flexural vibration

This paper is concerned with the question of whether there are two distinct spectra of frequencies for the transverse vibrations of Timoshenko beams as has been claimed by a number of prior authors for the case of the simply supported beam and, more recently, for beams supported in an arbitrary manner. Elementary analysis leads to the conclusion that there is only a single frequency spectrum; in the particular case of the simply supported beam the two frequency spectra viewpoint may be expedient as a device to compute frequencies but does not serve otherwise to explain the complex, dynamical behavior of Timoshenko beams.

83-522
Random Point Excitation of Coupled Beams
H.G. Davies and S.I. Khandoker
Dept. of Mech. Engrg., Univ. of New Brunswick, Fredericton, New Brunswick, Canada, J. Sound Vib., 84 (4), pp 557-562 (Oct 22, 1982) 5 figs, 5 refs

Key Words: Beams, Coupled systems, Random excitation, Point source excitation

Numerical results are presented for the power flow between two coupled beams, one of which is excited at a point by a random force. Frequency, spatial (over the excitation point) and ensemble (by varying the relative lengths of the beams) averages are compared with each other and with the results from simple statistical models such as SEA.

83-523
Mechanical Vibrations in Thermorheologically Simple Viscoelastic Beams and Plates
R.D. Marangoni and N. Basavanhally
Dept. of Mech. Engrg., Univ. of Pittsburgh, Pittsburgh, PA 15261, Intl. J. Solids Struc., 18 (11), pp 1007-1029 (1982) 14 figs, 5 tables, 21 refs

Key Words: Beams, Plates, Viscoelastic properties, Temperature effects

The problem of vibration of viscoelastic beams and plates subjected to a known transient temperature distribution and simply supported boundary conditions is solved using a Williams-type model expansion technique. The viscoelastic property ascribed is linear but otherwise general and its temperature dependence follows a thermorheologically simple viscoelastic law. The internal damping considered is proportional to the velocity of motion. The measured material relaxation is characterized using a Dirichlet Series which represents a Maxwell chain. The analytical solution is based upon superposing a time dependent static problem that contains the time-varying boundary conditions and a reduced dynamic problem that contains the inertia terms and the homogeneous boundary conditions. The integro-differential equation that results from the dynamic problem is solved numerically using a fourth order Runge-Kutta method.

83-524
Improved Numerical Computation of Uniform Beam Characteristic Values and Characteristic Functions
J.R. Gartner and N. Olgac
Dept. of Mech. Engrg., Univ. of Connecticut, Storrs, CT 06268, J. Sound Vib., 84 (4), pp 481-489 (Oct 22, 1982) 4 figs, 2 tables, 7 refs

Key Words: Beams, Flexural vibration, Bernoulli-Euler method

The problem of the lateral bending vibrations of a uniform cross-section Euler-Bernoulli beam has been treated by many investigators. The most widely accepted solution technique is to apply the method of separation of variables to the governing partial differential equation. In this manner the temporal and spatial portions of the solution can be treated individually. Several forms of the spatial characteristic function have been put forth by past investigators. The inherent problem which rises in the use of these characteristic functions is the numerical instability arising from the excessive magnitudes of the computed terms. These instabilities are especially noted in the computation of higher mode characteristic functions. A new form of the characteristic function is presented here which limits the magnitude of all terms to the approximate range of ±1. This is accomplished by avoiding all large, positive exponentials. The same concept is continued for the reliable evaluation of the system eigenvalues and other required parametric values.

83-525
Vibrations of Split Beams
J.T.S. Wang, Y.Y. Liu, and J.A. Gibby

Georgia Inst. of Tech., Atlanta, GA 30332, J. Sound Vib., 84 (4), pp 491-502 (Oct 22, 1982) 4 figs, 7 tables, 5 refs

Key Words: Beams, Discontinuity-containing media, Natural frequencies, Mode shapes

Free vibrations of beams containing split regions are investigated. General solutions for unsplit and split regions are first established. Recurrence equations relating integration constants for adjacent interior regions are established by satisfying continuity conditions at junctions of interior regions. The frequency determinant is then obtained by satisfying continuity conditions at junctions between end regions and interior regions immediately next to the end regions. Numerical examples are presented for illustrative purposes. Some numerical results are compared to results for a lumped mass model and to limited experimental measurements.

83-526

Structural Synthesis of Sandwich Beams with Outer Layers of Box-Section

J. Farkas and K. Jarmai

Dept. of Materials Handling Equipments, Technical Univ. for Heavy Industry, H-3515 Miskolc, Hungary, J. Sound Vib., 84 (1), pp 47-56 (Sept 8, 1982) 6 figs, 4 tables, 16 refs

Key Words: Beams, Sandwich structures, Vibration damping, Structural synthesis

It is proved by model measurements that for sandwich beams constructed from two rectangular tubes and a damping layer glued between them various calculation methods can be applied. A minimum cost design procedure is presented for a sandwich beam with constant cross-section. In a numerical example, constraints relating to the maximal dynamic stresses and deflection as well as local buckling of plate elements are considered.

83-527

The Design of Beams on Winkler-Pasternak Foundations for Minimum Dynamic Response and Maximum Eigenfrequency

S. Adali

Natl. Res. Inst. for Mathematical Sciences, Pretoria, South Africa, Rept. No. CSIR-TWISK-233, 36 pp (Sept 1981)

N82-27762

Key Words: Beams, Winkler foundations, Pasternak foundations, Natural frequencies, Design techniques

That cross sectional shape of a beam supported by a Winkler-Pasternak foundation is determined which will minimize the dynamic response of the beam or maximize its fundamental eigenfrequency. The dynamic response is defined either as the maximum dynamic deflection or the maximum dynamic normal stress when the beam is subject to a periodic dynamic load. To obtain the optimal designs, the methods of mathematical programming are employed, the area function being approximated by constant or linear splines on specified partitions. An iterative solution procedure is formulated that takes the form of successive steps of analysis and optimization. The effect of various problem parameters on the efficiency of the designs is investigated.

FRAMES AND ARCHES

(Also see No. 643)

83-528

Vibrations of Shallow Arches, Including the Effect of Geometric Non-Linearities

M.R.M. Crespo Da Silva

Dept. of Aerospace Engrg. and Applied Mechanics, Univ. of Cincinnati, Cincinnati, OH 45221, J. Sound Vib., 84 (2), pp 161-172 (Sept 22, 1982) 4 figs, 1 table, 20 refs

Key Words: Arches, Harmonic excitation, Geometric effects

The planar and non-planar motions of shallow arches of arbitrary shape, or of thin initially curved planar structural members, are investigated with the objective of determining the influence of non-straightness on the planar and non-planar response of the system to a planar harmonic excitation. Comparison is made with the response of a straight element having the same length as the curved member.

PANELS

(Also see No. 568)

83-529

Reasons and Means for Measuring the Spectral Density of the Pressure in a Subsonic Turbulent Boundary Layer

G. Maidanik and T. Eisler

David Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD 20084, J. Sound Vib., 84 (3), pp 397-416 (Oct 8, 1982) 12 figs, 11 refs

Key Words: Panels, Fluid-induced excitation, Power spectral density

A general operational formalism is introduced to describe the response of a plane structural surface (a panel) of finite impedance and the fluid media in which it is immersed. The formalism exhibits three basic elemental factors: the impedance of the uniform structural surface, the external drive, and the factor describing the interactions between these two factors via the impedance non-uniformities. Each of these three factors has an independent physical existence and is described by a model which is always, to some degree, an approximation. Compatibility of the approximations inherent in these factors is emphasized.

PLATES

(Also see No. 523)

83-530

Research on Dynamics of Composite and Sandwich Plates

C.W. Bert

School of Aerospace, Mech. and Nuclear Engrg., Oklahoma Univ., Norman, OK, Rept. No. OU-AMNE-82-3, TR-27, 40 pp (July 1982)
AD-A117 946

Key Words: Plates, Composite structures, Sandwich structures, Flutter

This report presents a survey of the literature concerning dynamics of plate-type structural elements of either composite material or sandwich construction. Papers from mid-1979 through early 1982 are reviewed, as are a few 1978 and early 1979 references. Particular attention is given to experimental research and to linear and nonlinear analysis. Configurations include rectangularly orthotropic, cylindrically orthotropic, and anisotropic plates; laminated plates; and thick and sandwich plates. Free and forced vibration, panel flutter, and impact are also considered.

83-531

Natural Frequencies of Circular Plates with Partially Free, Partially Clamped Edges

F.E. Eastep and F.G. Hemmig

Univ. of Dayton, Dayton, OH 45469, J. Sound Vib., 84 (3), pp 359-370 (Oct 8, 1982) 1 table, 10 refs

Key Words: Plates, Circular plates, Natural frequencies, Mode shapes, Finite element technique, Holographic techniques

The finite element method is used to predict numerically the natural frequencies and mode shapes of a vibrating circular plate with a partially free, partially clamped edge. A laser holography method is used to obtain experimentally the natural frequencies and mode shapes of the acoustically excited circular plate with mixed boundary conditions. The variation of frequency and mode shape with the free arc portion of the circular boundary are compared numerically and experimentally and are in excellent agreement. The mixed boundary conditions cause some of the higher modes to split into two branches with increasing arc length of the free boundary.

83-532

Internal and External Fields of Insonified Plates along Lamb Mode Branches of Zero Order

A. Freedman and G.G. Swinerd

65 Mount Pleasant Ave., Weymouth DT3 5JF, UK, J. Sound Vib., 83 (4), pp 479-500 (Aug 22, 1982) 13 figs, 2 tables, 15 refs

Key Words: Elastic waves, Plates, Submerged structures

A detailed investigation is presented of the reflection and transmission coefficients and of the internal displacement field along the branches of the A_0 and S_0 Lamb modes of a water-immersed, infinite steel plate insonified by a plane wave. The extensive numerical results presented are based on exact elastic theory.

83-533

Transient Response of Finite Plates Subjected to Surface Loadings

A.A. Lotfy

Ph.D. Thesis, Univ. of Waterloo, Canada (1982)

Key Words: Plates, Transient response

It is well known in the literature that the theory of elastodynamics can be used to find the transient response of plates subjected to symmetric or antisymmetric surface loading. There exists a good deal of information on the application of this theory to infinite and semi-infinite plates. However, the investigation of the finite plate transient response to end loadings has been taken up, only, recently. The aim of this thesis is to expand the study of the transient response of finite plates to include the case of surface loadings. This topic can be of great significance as it deals with the evaluation of a more general dynamic loading's influence on structures. The available approximate methods of analysis are not as capable of predicting the actual stress distribution during or after the application of the loadings as the stress wave analysis contained in this thesis.

83-534

Summed and Differential Harmonic Oscillations in a Circular Plate

K. Yasuda and N. Hayashi
Nagoya Univ., Furocho, Chikusaku, Nagoya, Japan, Bull. JSME, 25 (208), pp 1582-1590 (Oct 1982) 11 figs, 10 refs

Key Words: Plates, Harmonic excitation, Sum and difference frequencies

Various types of axisymmetric nonlinear forced oscillations are expected to occur in a circular plate subjected to harmonic excitation. The present paper conerns, among others, the summed and differential harmonic oscillations. Both theoretical and experimental analyses are conducted.

83-535

An Analytical Solution to the Problems of Three-Phonon Interaction and Second Harmonic Generation in a Solid Plate

T.S. Chao
Dept. of Physics, Georgetown Univ., Washington, DC, Rept. No. GUUS-08825, TR-5, 101 pp (Aug 1982) AD-A117 907

Key Words: Plates, Harmonic waves

A Green's function approach is used to determine the conditions under which it is possible to generate second harmonics of Lamb waves on solid plates and to have two Lamb waves interact to produce a third phonon (another Lamb mode).

83-536

Dynamic Finite Element Model for Laminated Structures

D.W. Pillasch, J.N. Majerus, and A.R. Zak
Dept. of Aeronautical and Astronautical Engrg., Univ. of Illinois at Urbana-Champaign, 104 S. Mathews Ave., Urbana, IL 61801, Computers Struc., 16 (1-4), pp 449-455 (1983) 6 figs, 7 refs

Key Words: Plates, Layered materials, Finite element technique

A finite element structural model is developed for the dynamic analysis of laminated, thick plates. The model uses quadrilateral elements to represent the shape of the plate and the elements are stacked in the thickness direction to represent various material layers. This analysis allows for orthotropic, elastic-plastic or elastic-viscoplastic material properties. Nonlinear strain displacement relations are used to represent large transverse plate deflection. A finite difference technique is used to perform the numerical time integration.

83-537

Dynamic Response of Viscoelastic Plates of Arbitrary Shape to Rapid Heating

D. Hill, J. Mazumdar, and D.L. Clements
Dept. of Applied Mathematics, The Univ. of Adelaide, South Australia, Intl. J. Solids Struc., 18 (11), pp 937-945 (1982) 6 figs, 1 table, 13 refs

Key Words: Plates, Viscoelastic properties, Temperature effects

The dynamic behavior of viscoelastic plates of arbitrary shape subjected to elevated temperatures is examined. Using a method based upon the concept of isoamplitude contour lines in conjunction with isothermal contour lines on the surface of the plate, a simple general approach for the study of thermally induced vibrations of a viscoelastic plate is presented. The resulting method of solution is applied to study the response of a viscoelastic plate in the form of a hollow elliptical annulus and a viscoelastic rectangular plate under a thermal shock at the center.

83-538

Free Vibration of a Stiffened Trapezoidal Cantilever Plate

T. Irie, G. Yamada, and H. Ida
Dept. of Mech. Engrg., Faculty of Engrg., Hokkaido Univ., Kita-13, Nishi-8, Kita-ku, Sapporo, 060 Japan, J. Acoust. Soc. Amer., 72 (5), pp 1508-1513 (Nov 1982) 5 figs, 2 tables, 17 refs

Key Words: Plates, Cantilever plates, Stiffened plates, Natural frequencies, Mode shapes

An analysis is presented for the free vibration of a stiffened trapezoidal cantilever plate. For this purpose, a trapezoidal plate is transformed into a square plate of unit length by the transformation of variables. The transverse deflection of the transformed square plate is expressed in a series of the products of the deflection functions of a cantilever beam and a free-free beam parallel to the edges of the plate, and the frequency equation is derived by the Ritz method. The elements of the equation are calculated by numerical integration. The present method is applied to square, parallelogram, or trapezoidal cantilever plates with several stiffeners; the natural frequencies and the mode shapes are calculated numerically up to higher modes, and the effects of stiffeners on the vibration are studied.

83-539

Large Amplitude Free Vibrations of a Right Angled Isosceles Triangular Plate of Simply Supported Edges

S.K. Chaudhuri

Dept. of Mathematics, Acharya B.N. Seal College, Cooch-Behar, West Bengal, India, J. Sound Vib., 84 (1), pp 81-85 (Sept 8, 1982) 3 figs, 10 refs

Key Words: Plates, Triangular bodies, Free vibration, Large amplitudes

An analysis of large amplitude free vibrations of a right angled isosceles triangular plate of simply supported edges is given, based on the von Kármán field equations expressed in terms of displacement components. The differential equations involving the in-plane displacements are solved completely. A second order nonlinear differential equation for the unknown time function is obtained by means of Galerkin's procedure and solved in terms of Jacobian elliptic functions. Numerical results are presented graphically and a comparison of these with results obtained from a Berger-type analysis is made.

83-540

Axisymmetric Vibrations of a Vessel with Variable Thickness

K. Suzuki, M. Konno, T. Kosawada, and S. Takahashi
Faculty of Engrg., Yamagata Univ., Yonezawa, Japan, Bull. JSME, 25 (208), pp 1591-1600 (Oct 1982) 15 figs, 6 refs

Key Words: Shell-plate systems, Geometric effects, Natural frequencies, Mode shapes

The axisymmetric vibrations of a vessel with variable thickness composed of a cylindrical shell and two circular plates as its lids are investigated. The Lagrangian of the vessel is obtained expressed by quadratic forms of unknown boundary values and the frequency equations are obtained from the minimum condition of the Lagrangian.

83-541

The Response of a Fluid-Loaded, Beam-Stiffened Plate

G.P. Eatwell and D. Butler

School of Mathematics, Univ. of Bath, Claverton Down, Bath BA2 7AY, UK, J. Sound Vib., 84 (3), pp 371-388 (Oct 8, 1982) 8 figs, 14 refs

Key Words: Plates, Beam-plate systems, Fluid-induced excitation

Expressions are obtained for the vibration of and sound radiation from a fluid-loaded elastic plate which is stiffened by a finite number of parallel beams. The expressions are evaluated asymptotically in the far field and results for point and line excitation of a plate with equally spaced beams compared with those for a corresponding periodically stiffened plate.

83-542

The Dynamics of Repeated Impacts with a Sinusoidally Vibrating Table

P.J. Holmes

Dept. of Theoretical and Appl. Mech. and Ctr. for Appl. Mathematics, Cornell Univ., Ithaca, NY 14853, J. Sound Vib., 84 (2), pp 173-189 (Sept 22, 1982) 10 figs, 35 refs

Key Words: Plates, Vibrating structures, Impact response, Balls

A deceptively simple difference equation is derived which approximately describes the motion of a small ball bouncing vertically on a massive sinusoidally vibrating plate. In the case of perfect elastic impacts, the equation reduces to the standard mapping which has been extensively studied by physicists in connection with the motions of particles constrained in potential wells. It is shown that, for sufficiently large excitation velocities and a coefficient of restitution close to one, this deterministic dynamical system exhibits large families of irregular non-periodic solutions in addition to the expected harmonic and subharmonic motions. The physical significance of these and other chaotic motions which appear to occur frequently in nonlinear oscillations is discussed.

SHELLS

(Also see No. 540)

83-543

Vibration and Buckling of Cylinders with Elliptical Cross Section

K. Shirakawa and M. Morita
Dept. of Mech. Engrg., Univ. of Osaka Prefecture, Mozu-Umemachi, Sakai, Osaka 591, Japan, J. Sound Vib., 84 (1), pp 121-131 (Sept 8, 1982) 6 figs, 1 table, 16 refs

Key Words: Shells, Cylindrical shells, Free vibration

A study of the free vibration of finite cylinders with elliptical cross section under external pressure is presented. The buckling pressure is obtained as a special case in the free vibration analysis. The elliptical cross section is considered to be composed of two circular arcs, and the equations of a circular cylindrical shell are applied. Numerical examples are presented to examine the effect of out-of-roundness on the natural frequencies and the buckling pressure.

83-544

An Analytical Model for Ovalling Oscillation of Clamped-Clamped Cylindrical Shells in Cross Flow

M.P. Paidoussis, S.J. Price, and H.-C. Suen
Dept. of Mech. Engrg., McGill Univ., Montreal, Quebec, Canada, J. Sound Vib., 83 (4), pp 555-572 (Aug 22, 1982) 5 figs, 4 tables, 19 refs

Key Words: Shells, Cylindrical shells, Fluid-induced excitation, Aeroelasticity, Wind-induced excitation, Chimneys

A quasi-static aeroelastic theory for predicting the ovalling oscillations of thin cylindrical shells in cross flow is presented. The flow is treated as a superposition of the measured viscous mean flow and a potential flow associated with deformation of the shell. The aerodynamic forces are formulated by means of strip theory and the dynamics of the shell are described by means of Flügge's equations.

83-545

Ovalling Oscillations of Cantilevered and Clamped-Clamped Cylindrical Shells in Cross Flow: An Experimental Study

M.P. Paidoussis, S.J. Price, and H.-C. Suen
Dept. of Mech. Engrg., McGill Univ., Montreal, Quebec, Canada, J. Sound Vib., 83 (4), pp 533-553 (Aug 22, 1982) 13 figs, 5 tables, 19 refs

Key Words: Shells, Cylindrical shells, Wind tunnel testing, Fluid-induced excitation, Wind-induced excitation, Chimneys

Some experiments on cantilevered, thin cylindrical shells in cross flow are presented, as well as experiments with shells clamped at both ends and spanning the wind tunnel test section. Ovalling oscillations were found to occur mainly in the second, third, fourth and fifth circumferential modes of these shells, in both first and second axial modes, for both types of support condition, the critical mode numbers depending mainly on shell geometry.

RINGS

83-546

Vibration of a Two Layered Ring on Periodic Radial Supports

E.S. Reddy and A.K. Mallik
Dept. of Mech. Engrg., Indian Inst. of Tech., Kanpur 208016, India, J. Sound Vib., 84 (3), pp 417-430 (Oct 8, 1982) 8 figs, 1 table, 20 refs

Key Words: Rings, Layered materials, Radial supports, Resonant frequencies

Natural frequencies of a two layered elastic ring, on equispaced, identical radial supports, are obtained by using a wave approach. Two types of support conditions are investigated. With the outer layer viscoelastic, the theory of forced damped normal modes is used to obtain the resonant frequencies and the modal loss factors of the structure. Results presented show the effect of the thickness ratio on the resonant frequency and the modal loss factor. The effect of rotational constraints at the supports is also reported.

PIPES AND TUBES

83-547

Computation of Acoustic Power, Vibration Response and Acoustic Pressures of Fluid-Filled Pipes

J.H. James

Admiralty Marine Technology Establishment, Teddington, UK, Rept. No. AMTE(N)-82036, DRIC-BR-83735, 20 pp (May 1982)
AD-A117 418

Key Words: Pipes (tubes), Fluid-filled containers, Time-dependent parameters, Harmonic excitation, Point source excitation

The time-harmonic excitation is either an interior point source of sound or a mechanical point force located on the pipe's surface. The acoustic power radiated into the exterior fluid, the vibration response of the pipe's wall, and the pressures in the exterior and interior fluids are computed by a simple integration scheme. Numerical results are presented for the case of a water-filled steel pipe that is surrounded by air.

83-548
Reduce Noise in Process Piping
J.G. Seebold
Standard Oil Co. of California, San Francisco, CA, Hydrocarbon Processing, 61 (10), pp 75-79 (Oct 1982) 9 figs

Key Words: Piping systems, Valves, Noise reduction

An in-depth discussion of the sources of noise in piping (primarily valves and machinery) and techniques for reducing it are presented. Effective noise control is achieved by substituting valves of special design that change the physics of the internal flow, or by treating the transmission path. Studies show that generally, for valves in gas service, most of the energy remains in the gas and in-line silencers are most effective. Acoustic lagging is not the best method for dealing with noise emanating from piping systems.

83-549
A Comparative Study of Combination Methods Used in Response Spectrum Analysis of Nuclear Piping Systems
S. Gupta, D.P. Jhaveri, O. Kustu, and J.A. Blume
URS/John A. Blume & Associates, San Francisco, CA, ASME Paper No. 82-PVP-56

Key Words: Piping systems, Nuclear reactor components, Response spectra

The different methods of combining responses from individual modes and directions for response spectrum analysis of nuclear piping systems are evaluated. For the purpose of the study, dynamic responses of 20 typical piping systems using nine different combination methods are systematically compared.

83-550
Prevention of Flow Induced Vibration and Thermal Stresses in the Construction of Facilities (Strömungsbedingte Schwingung und Wärmespannung im Anlagenbau vermeiden)
W. Wagner
Maschinenmarkt, 87, pp 1862-1864 (Nov 2, 1982) 5 figs, 3 refs
(In German)

Key Words: Tube arrays, Pipes (tubes), Heat exchangers, Resonant response, Temperature effects, Fatigue life, Vibration control, Fluid-induced excitation

In order to prevent vibration-induced failures of facilities, the condition of resonance between the excitation and natural frequencies should be avoided. Such vibrations occur frequently in the tube bundles of heat exchangers. Thermal stresses occur where thermal fluctuations are present. This alternating loading leads to fatigue failure. The article describes how such conditions can be prevented.

83-551
A Simplified Method for Determining Acoustic and Tube Eigenfrequencies in Heat Exchangers
J. Planchard, F.N. Remy, and P. Sonneville
Electricité de France, Direction des Etudes et Recherches, Clamart, France, J. Pressure Vessel Tech., Trans. ASME, 104 (3), pp 175-179 (Aug 1982) 6 figs, 5 tables, 16 refs

Key Words: Tube arrays, Fluid-induced excitation, Natural frequencies

A method of computation of eigenfrequencies of large tube arrays is presented, which is based on homogenization techniques. It is supposed that the fluid is compressible, at rest and contained in a cavity; the bundle geometry is assumed to be repetitive; an equivalent sound velocity through the tubes can then be calculated, and the fluid-structure interaction is taken into account. A new eigenvalue problem is so obtained, defined over a simpler domain; i.e., the region occupied by both fluid and tubes. It is then easy to solve it for computing the eigenfrequencies of the coupled system. Numerical and experimental results are presented and some details of the experimental apparatus are given.

83-552

A Theoretical Model for Fluid-Elastic Instability in Heat Exchanger Tube Bundles

J.H. Lever and D.S. Weaver

Dept. of Mech. Engrg., McMaster Univ., Hamilton, Ontario, Canada, J. Pressure Vessel Tech., Trans. ASME, 104 (3), pp 147-158 (Aug 1982) 7 figs, 30 refs

Key Words: Tube arrays, Heat exchangers, Fluid-induced excitation

A simple theoretical model is developed from first principles for the fluid-elastic instability in heat exchanger tube bundles. A series of experiments are conducted to verify the basic assumption that only a single tube need be modeled in a flow channel which preserves the basic geometry of the array. The mechanism of instability is found to be one of flow redistribution due to tube motion and a phase lag resulting from fluid inertia. Agreement is found with available experimental data for a parallel triangular array without the need for empirical fluid force coefficients.

83-553

The Cross-Flow Response of a Tube Array in Water – A Comparison with the Same Array in Air

D.S. Weaver and D. Koyoyannakis

Dept. of Mech. Engrg., McMaster Univ., Hamilton, Ontario, Canada, J. Pressure Vessel Tech., Trans. ASME, 104 (3), pp 139-146 (Aug 1982) 10 figs, 1 table, 23 refs

Key Words: Tube arrays, Fluid-induced excitation

A water tunnel study was conducted on a parallel triangular array of tubes with a pitch ratio of 1.375. The array was geometrically identical to that used previously in a wind tunnel study so that the tube response to cross flow could be compared. It was seen that the response curves for tube arrays in water are much less regular than those in air, creating ambiguity in defining the stability threshold. The irregularities are seen to be associated with shifts in relative tube mode and frequency.

83-554

Transition to Turbulence in a Pulsatile Pipe Flow. Part 2: Characteristics of Reversing Flow Accompanied by Relaminarization

M. Iguchi and M. Ohmi

Osaka Univ., Yamadaoka 2-1, Suita, Osaka, Japan, Bull. JSME, 25 (208), pp 1529-1536 (Oct 1982) 6 figs, 1 table, 11 refs

Key Words: Pipes (tubes), Turbulence

The instantaneous velocity distributions and pressure gradients in a reversing pulsatile flow and an oscillatory flow in which turbulent bursts follow by relaminarization in the same cycle are investigated. They are predicted with sufficient accuracy by the theory for a transient pulsatile laminar flow in the laminar phase. In the phase where turbulence with higher frequency appears, they are well approximated by the well-known 1/7 power law and the turbulent quasi-steady friction law, respectively.

83-555

Distorted Pressure Histories Due to the Step Responses in a Linear Tapered Pipe (5th Report, Case of a Tank Being Installed at the End)

T. Tanahashi, Y. Yamashita, T. Sawada, and T. Ando

Keio Univ., 3-14-1, Hiyoshi, Kohoku-ku, Yokohama, Japan, Bull. JSME, 25 (208), pp 1521-1528 (Oct 1982) 4 figs, 8 refs

Key Words: Pipes (tubes), Variable cross section, Step response, Helmholtz resonators

Distorted pressure histories in a linear tapered tube equipped with a tank at the end are experimentally investigated by the step pressure input. This problem is theoretically solved by two methods: eigenfunction expansion and asymptotic expansion.

DUCTS

83-556

An Experimental Investigation of Pure Tone Generation by Vortex Shedding in a Duct

H. Nomoto and F.E.C. Culick

California Inst. of Tech., Pasadena, CA 91125, J. Sound Vib., 84 (2), pp 247-252 (Sept 22, 1982) 5 figs, 7 refs

Key Words: Ducts, Noise generation, Vortex shedding

An experimental investigation is carried out for acoustic oscillations sustained by flow through a duct containing two baffles. Pure acoustic tones corresponding to longitudinal resonant modes of the duct are produced when certain flow and geometrical conditions are satisfied. The conditions are such as to ensure close coincidence between the frequency of vortex shedding from the forward baffle, and a natural frequency of the duct. Flow visualization shows that under these conditions a stable vortex structure exists between the baffles, containing at all times an integral number of vortices.

83-557

Boundary Layer Effects on Sound in a Circular Duct

R.T. Nagel and R.S. Brand

Dept. of Mech. and Aerospace Engrg., North Carolina State Univ., Raleigh, NC 27650, J. Sound Vib., 85 (1), pp 19-29 (Nov 8, 1982) 7 figs, 17 refs

Key Words: Ducts, Sound waves, Boundary layer excitation

Boundary layer effects on an acoustic field in a unidirectional flow with transverse shear are studied. The acoustic pressure variation in the direction normal to that of the flow is governed in the boundary layer by a second order differential equation. The problem in the boundary layer is reduced from a two point boundary value problem to a one point boundary value problem by transforming the governing equation into the Riccati equation. The Riccati equation is easily integrated with standard numerical procedures.

83-558

Development of a Sound Radiation Model for a Finite-Length Duct of Arbitrary Shape

M.A. Hamdi and J.M. Ville

Universite de Technologie de Compiegne, Cedex, France, AIAA J., 20 (12), pp 1687-1692 (Dec 1982) 16 figs, 2 tables, 7 refs

Key Words: Ducts, Sound waves, Sound propagation

A new variational formulation by integral equations has been developed to solve Helmholtz's equation with mixed boundary conditions. Contrary to previous methods generally based on the Wiener-Hopf technique which are limited to the case of a circular semi-infinite duct, this method allows the computation of sound radiation from the duct with arbitrary shape and finite length. Experimental works have been conducted using a spinning mode synthesizer. Comparison between theoretical and experimental results of pressure reflection coefficients for two inlet shapes and directivity patterns shows a very good agreement.

83-559

Evaluation of Four-Pole Parameters for Ducts with Flow by the Finite Element Method

K.S. Peat

Dept. of Engrg. Mathematics, Univ. of Tech., Loughborough LE11 3TU, UK, J. Sound Vib., 84 (3), pp 389-395 (Oct 8, 1982) 4 figs, 7 refs

Key Words: Ducts, Elastic waves, Sound waves, Wave propagation, Finite element technique

A finite element formulation of the equations of acoustic wave propagation in the presence of a mean flow of low Mach number is obtained. The resulting equation system is solved with two different sets of boundary conditions in order to obtain the four-pole parameters of a specified section of duct. The results are compared with those of existing one-dimensional models of the flow. The work is intended to aid in the prediction of the insertion loss of intake silencers on internal combustion engines.

83-560

Mode Scatterer Design for Fan Noise Suppression in Two-Dimensional Ducts

M.S. Tsai

Boeing Commercial Airplane Co., Seattle, WA, J. Sound Vib., 83 (4), pp 501-512 (Aug 22, 1982) 3 figs, 7 tables, 11 refs

Key Words: Fan noise, Noise reduction, Ducts, Acoustic linings

The favorable scattering associated with the transfer of the lower order modal energies to the higher ones can be induced only when the lower frequency waves propagate in the inlet duct or in the no mean flow conditions, and the first lining which the incident waves from the fan face meet is a nearly reactive one. The phases of the incident waves from the noise source will affect the performance of the scatterer, but not the selection of the optimized scatterer. For a given baseline lining, the reactance and the length of the scatterer are the coupling factors in the determination of an optimized scatterer.

BUILDING COMPONENTS
(Also see No. 648)

83-561
Sound Radiation from Building Elements
Y. Shen and D.J. Oldham
Dept. of Bldg. Science, Univ. of Sheffield, Sheffield S10 2TN, UK, J. Sound Vib., 84 (1), pp 11-33 (Sept 8, 1982) 9 figs, 4 tables, 21 refs

Key Words: Structural members, Plates, Sound transmission

The directivity patterns of typical building elements, a large concrete panel and a glazed window, are calculated. The two elements are treated as homogeneous plates. The Galerkin method is used to calculate the forced vibration patterns of these plates due to exposure to a uniform sound field. Rayleigh's far field approximation is then used to calculate the sound level due to the plate vibrations at distant points and a directivity pattern is thus built up. The effect on the radiation patterns of varying the loss factor of internal damping, the frequency of excitation and the boundary conditions is investigated.

83-562
Sound Insulation of Stepped or Staggered Walls of Plastered Masonry
E.C. Sewell
Bldg. Res. Station, Garston, Watford WD2 7JR, UK, J. Sound Vib., 84 (4), pp 463-480 (Oct 22, 1982) 4 figs, 4 tables, 8 refs

Key Words: Walls, Noise reduction

It is suggested that a step (vertical displacement) or stagger (horizontal displacement) enhances the sound insulation between dwellings separated by a cavity party wall of plastered masonry mainly through reducing the coupling between corresponding modes of the two leaves, with only a secondary effect from the reduction in common area. A comparison between the insulation ratings found in field measurements across stepped and/or staggered walls with those for similar in-line party walls confirms that displacement significantly enhances insulation, but the experimental data are inconclusive in regard to the size of the effect.

83-563
Cumulative Damage in Steel Structures Subjected to Earthquake Ground Motions
H. Krawinkler and M. Zohrei
Dept. of Civil Engrg., Stanford Univ., Stanford, CA 94305, Computers Struc., 16 (1-4), pp 531-541 (1983) 17 figs, 5 refs

Key Words: Structural members, Steel, Fatigue tests, Seismic response

Experimental data are presented from low cycle fatigue tests of structural steel components. In these tests the failure modes of local buckling in beam flanges and fracture at weldments are studied in detail. Cumulative damage models are proposed which permit a life prediction for arbitrary cyclic loading histories. For the local buckling failure mode a series of linear damage models is used to predict deterioration threshold and deterioration, whereas a single model is used for the fracture mode. Crack propagation at weldments is modeled with a crack growth rate model based on the plastic strain range. Adequate predictions of lives were obtained from the analytical models.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION
(Also see Nos. 615, 630)

83-564
Laminated Steels Cut Noise and Vibration
J. Moon
Diesel Prog., 48 (10), pp 22, 27-28 (Oct 1982) 4 figs

Key Words: Engine noise, Noise reduction, Layered materials, Steel

A new type of laminated steel, called MPM (metal-plastic-metal), for use as a noise reducing material in engine and vehicle designs is described. The material has not only the desired acoustic properties, but also offers advantages in terms of lightness and cost-savings compared with other methods of noise damping.

83-565
Acoustic Intensity Measurements for Small Engines
J.K. Thompson
Dept. of Mech. Engrg., Louisiana State Univ., Baton Rouge, LA 70803, Noise Control Engrg., 19 (2), pp 56-63 (Sept-Oct 1982) 12 figs, 12 refs

Key Words: Engine noise, Noise measurement, Sound power levels, Noise source identification

The difficulties encountered in two-microphone acoustic measurements of a 14.9 kW (8 hp) engine are described. The sound power levels determined for the major engine sources are compared to results obtained from conventional source identification measurements.

83-566
Acoustic Behavior of Laminated Sheet Metal (Das akustische Verhalten geschichteter Bleche)
U. Bernhardt
Fortschritt-Berichte VDI-Zt., Series 11, No. 49, 142 pp (1982) 58 figs, 1 table. Summarized in VDI-Z, 124 (20), pp 776 (Oct 1982). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany, Price: 82.-DM
(In German)

Key Words: Noise reduction, Machinery noise, Metals

The use of layered riveted sheet material for noise reduction in machinery, instead of conventional sheet metal bonded by high damping materials, is discussed. The noise reduction is accomplished by the air layer trapped between the sheets -- the thinner the air layer, the higher the noise reduction. Thus, higher noise reductions with thinner materials may be obtained, without the disadvantages of temperature dependence, the danger of layer separation or the insufficient resistance under rough operating conditions.

83-567
A Mathematical Model for Noise Propagation Between Buildings
H. Kuttruff
Institut f. Technische Akustik der Rheinisch-Westfalischen Technischen Hochschule Aachen, Aachen, Germany, J. Sound Vib., 85 (1), pp 115-128 (Nov 8, 1982) 7 figs, 1 table, 11 refs

Key Words: Sound propagation, Buildings

Noise propagation in residential areas and similar environments is characterized by multiple scattering of sound between buildings. Approximate solutions to this problem ar· obtained by modeling this type of propagation as diffusion of incoherent sound particles. These solutions describe the gross dependence of sound energy density on the distance from the noise sources(s); the relevant parameters of the environment are the (average) height, scattering cross section and absorption of the buildings. Particular consideration is given to the propagation of noise from freely flowing traffic, for which not only average values of the energy density but also expressions describing the range and frequency of fluctuations are presented.

83-568
Noise Transmission into Semicylindrical Enclosures through Discretely Stiffened Curved Panels
M.T. Chang and R. Vaičaitis
Dept. of Civil Engrg. and Engrg. Mech., Columbia Univ., New York, NY 10027, J. Sound Vib., 85 (1), pp 71-83 (Nov 8, 1982) 5 figs, 21 refs

Key Words: Enclosures, Panels, Curved plates, Noise transmission, Modal analysis, Finite strip method

An analytical study of sound transmission into semicylindrical enclosures through discretely stiffened curved elastic panels is presented. The transmitted sound is estimated by solving the acoustic wave equation for the interior acoustic field, a Galerkin-like method being used. This solution is then coupled to the vibration of the stiffened panels. The response characteristics of these panels are determined by using a modal analysis where the modes are obtained by the finite element-strip method. Numerical results include spectra of the interior sound pressure due to white noise, turbulent boundary layer and propeller noise inputs.

83-569
Noise Control in the Design of Process Plants
J.B. Erskine
Imperial Chemical Industries, Ltd., North East Region Engrg. Dept., Billingham, Cleveland, UK, Instn. Mech. Engrs., Proc., 196, pp 199-216 (Sept 1982) 24 figs, 8 tables, 20 refs

Key Words: Industrial facilities, Noise reduction

The design of process plants must incorporate noise control since retro-fitting is impractical on both technical and economic grounds. While the method of approach depends on particular circumstances, key factors common to all projects are: setting of realistic specifications; establishing working procedures which ensure full co-operation by all members of the design team; early identification of the most difficult problems so that the most economic solutions can be generated; utilization of good and bad experience from previous projects to minimize noise control costs, this forms the basic work load in most projects; evaluation of the completed plant so that the degrees of success can be determined and lessons can be learned for future projects. These, and some technical aspects, are covered in this paper.

83-570

Vibration Characteristics of Brass Instrument Bells

P.S. Watkinson and J.M. Bowsher
Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK, J. Sound Vib., 85 (1), pp 1-17 (Nov 8, 1982) 5 figs, 3 tables, 12 refs

Key Words: Bells, Musical instruments, Natural frequencies, Mode shapes, Acoustic excitation, Vibration response, Finite element techniques

Finite element techniques are used to study the mode frequencies and shapes of trombone bells. The responses of the modes to acoustic excitation are calculated and general response levels presented.

83-571

Reflection of Sound by a Boundary Layer

R.S. Brand and R.T. Nagel
Dept. of Mech. Engrg., Univ. of Connecticut, Storrs, CT 06268, J. Sound Vib., 85 (1), pp 31-38 (Nov 8, 1982) 6 figs, 8 refs

Key Words: Sound reflection

A method is given for the calculation of the reflection coefficient for plane waves incident upon a plane boundary when the acoustic medium flows parallel to the plane and the resulting boundary layer is of finite thickness. Results are given for limited ranges of the important parameters, which are the Mach number of the flow, the angle of incidence, the thickness of the boundary layer, and the acoustic admittance of the solid boundary.

83-572

Are Earth Berms Acoustically Better than Thin-Wall Barriers

J.J. Hajek
Res. and Dev. Branch, Ontario Ministry of Transportation and Communications, 1201 Wilson Ave., Downsview, Ontario, Canada M3M 1J8, Noise Control Engrg., 19 (2), pp 41-48 (Sept/Oct 1982) 9 figs, 29 refs

Key Words: Noise barriers

The two most common highway noise barrier structures are earth berms and thin-walls. Yet, the relative acoustical performance of these barriers is not completely understood. Preliminary results of testing indicate that thin-walls and earth berms of the same height are about equally effective in reducing noise. The acoustical effectiveness of wall/earth berm combinations is found to be quite similar to that of thin-walls alone. The practice of erecting relatively low walls on top of earth berms was found to be an acoustically good solution.

83-573

Traffic Noise Generation of Asphalt Road Surfaces

A.T. Visser and R.N. Walker
Natl. Inst. for Transport and Road Research, Pretoria, South Africa, 14 pp (1981) (Presented at Intl. Symp. on Transportation Noise, Pretoria, Oct 21-23, 1981)
N82-27872

Key Words: Traffic noise, Noise generation

The noise generating properties of different asphalt road surfacing types are considered. Noise levels at low and high speeds were investigated.

SHOCK EXCITATION

(Also see Nos. 437, 456, 471)

83-574

Application of the Finite Element Method for the Evaluation of Velocity Response of Anvils

C.W.S. To
Dept. of Mech. Engrg., Univ. of Calgary, Calgary, Alberta, Canada T2N 1N4, J. Sound Vib., 84 (4), pp 529-548 (Oct 22, 1982) 7 figs, 5 tables, 16 refs

Key Words: Anvils, Hammers, Damped structures, Transient excitation, Finite element technique, Natural frequencies, Mode shapes, Computer programs

The acoustic energy radiating from an elastic structure is directly related to the spatial average of the mean square velocity response of the structure to excitation. A theory for evaluating the velocity response of unconstrained and constrained, damped structures, discretized by the finite element method, to transient excitations is given. A numerical approach employing the normal mode-cum-recursive digital filtering technique for the determination of velocity response of damped structures to arbitrary transient excitations is also included.

83-575
Evolution and Diffraction of Random Waves in Solids
A.I. Beltzer
School of Aerospace, Mech. and Nuclear Engrg., Univ. of Oklahoma, 865 Asp Avenue, Room 212, Norman, OK 73019, Computers Struc., 16 (1-4), pp 495-498 (1983) 5 figs, 16 refs

Key Words: Wave propagation, Random waves

This paper presents a survey of recent results obtained on random waves propagating in regular (nonrandom) solid media. Applications to materials science and the dynamics of embedded structures are discussed.

83-576
Weak Shock Waves in Heat Conducting Thermoelastic Materials
E. Ukeje
Dept. of Mathematics, Univ. of Nigeria, Nsukka, Nigeria, Intl. J. Engrg. Sci., 20 (12), pp 1275-1290 (1982) 3 figs, 16 refs

Key Words: Shock wave propagation

An attempt is made to study the propagation of weak shock waves in heat conducting materials. The equation for determining the velocities of propagation is derived and expressions for the velocities in linear elastic materials are obtained. The equations governing the growth and decay of the wave amplitude are obtained and studied for shock waves of arbitrary form in linear thermoelastic body.

83-577
Bulk Cavitation in a Vertical Water Filled Shock Tube
M.R. Driels
Dept. of Mech. Engrg., Univ. of Edinburgh, Edinburgh EH9 3JL, UK, J. Sound Vib., 84 (4), pp 563-572 (Oct 22, 1982) 9 figs, 1 table, 6 refs

Key Words: Shock wave propagation, Underwater structures, Shock tube testing, Cavitation

A one dimensional lumped parameter theoretical model is developed to predict the occurrence of recompaction waves associated with bulk cavitation following the reflection of a pressure pulse from a free surface. Experimental data is obtained from a simple shock tube for comparison with the theoretical model and with that of Cushing whose work covers the classic explosion pulse. It is concluded that the model presented here predicts the occurrence of recompaction waves reasonably well and can have significant advantages over previously published work.

83-578
Nuclear Blast Response of Airbreathing Propulsion Systems: Laboratory Measurements with an Operational J-85-5 Turbojet Engine
M.G. Dunn and J.M. Rafferty
Aerodynamic Res. Dept., Calspan Advanced Tech. Ctr., Buffalo, NY 14225, J. Engrg. Power, Trans. ASME, 104 (3), pp 624-632 (July 1982) 14 figs, 7 refs

Key Words: Turbojet engines, Nuclear explosion effects, Shock waves, Experimental test data

This paper describes an experimental technique that has been developed for the performance of controlled laboratory measurements of the nuclear blast response of airbreathing propulsion systems.

83-579
Nuclear Air Blast Effects
M. Fry
Science Applications, Inc., McLean, VA, Rept. No. SAI-83-836-WA, 98 pp (June 1982)
AD-A117 436

Key Words: Air blast, Shock waves, Nuclear weapons effects

The accomplishments achieved over the contract period are documented. Computational results for nuclear and conventional airblast are presented. Improvements in the numerical algorithms are discussed. Theoretical computation of shock waves is compared with available data.

83-580

Shock-Fitted Euler Solutions to Shock Vortex Interactions

M.D. Salas, T.A. Zang, and M.Y. Mussaini
NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-84481, 20 pp (May 1982)
N82-28061

Key Words: Shock waves, Spectrum analysis, Finite difference method

The interaction of a planar shock wave with one or more vortexes is computed using a pseudospectral method and a finite difference method. The development of the spectral method is emphasized. In both methods the shock wave is fitted as a boundary of the computational domain. The results show good agreement between both computational methods.

83-581

Characterization of the Shock Attenuation Properties of Lightly Compacted Damp Earth

G.W. Dyckes
Sandia Natl. Labs., Albuquerque, NM, Rept. No. SAND-81-1853, 15 pp (Aug 1981)
DE82008489

Key Words: Ground shock, Shock wave attenuation

The shock-mitigating properties of lightly compacted damp alluvium placed over hemispherical surface charges of composition C-4 explosive are described.

83-582

Blunt Fin-Induced Shock Wave/Turbulent Boundary-Layer Interaction

D.S. Dolling and S.M. Bogdonoff
Princeton Univ., Princeton, NJ, AIAA J., 20 (12), pp 1674-1680 (Dec 1982) 15 figs, 28 refs

Key Words: Interaction: shock waves-boundary layer

Results from an experimental study of blunt fin-induced shock wave/turbulent boundary-layer interaction are presented. Semi-infinite fin models with hemicylindrical, unswept leading edges were tested in Mach 3, high Reynolds number, turbulent boundary layers. The program had two fundamental objectives. The first was to examine the spanwise development of the disturbed flowfield and to determine its dependence on the configuration geometry and incoming flow conditions. The second objective was to determine the vertical extent of the interaction on the fin.

83-583

Investigations of Mach Reflection of a Shock Wave (Part 1, Configurations and Domains of Shock Reflection)

T. Ikui, K. Matsuo, T. Aoki, and N. Kondoh
Kyushu Univ., Hakozaki Fukuoka, 812, Japan, Bull. JSME, 25 (208), pp 1513-1520 (Oct 1982) 11 figs, 13 refs

Key Words: Shock wave reflection, Walls

When a plane moving shock wave encounters an inclined wall, it is reflected by the wall. In these reflection problems, four different types of reflection have been observed in previous shock tube experiments: regular reflection, single-Mach, complex-Mach, and double-Mach reflections. In the present study, the reflection phenomena of the shock waves are investigated experimentally over a wide range of incident shock Mach numbers and wedge angles using air or chlorofluoro-carbon (Freon-12), as a working gas. In the experiment using Freon-12, a new type of reflection which cannot be classified into any one of the above four types is observed. The domains where these five types of reflection can occur and the transition boundaries from one type of reflection to another are discussed.

83-584

A Study of Power Spectral Density of Earthquake Accelerograms

P. Moayyad
Ph.D. Thesis, Southern Methodist Univ., 313 pp (1982)
DA8219435

Key Words: Earthquakes, Power spectral density, Time-dependent parameters

An examination of recorded earthquake accelerograms indicates their nonstationary characteristics; that is, their statistical properties vary with time. The nonstationary characteristic takes a special form when the strong motion part of the record is considered. It is demonstrated in this study that within the strong motion duration the short time mean square value varies with time, whereas the frequency structure of the record remains time-invariant. This conclusion leads to the assumption that the strong motion segments of accelerograms can be considered to form a locally stationary random process. The power spectral density of such a process is a function of both time and frequency.

83-585

Optimized Earthquake Simulation for High-Reliability Aseismic Design

A. Baratta

Istituto di Costruzioni - Facolta' di Architettura, Univ. of Naples, I-80134, Naples, Italy, Nucl. Engrg. Des., 71 (3), pp 299-300 (Aug 11, 1982) 1 fig, 2 refs

Key Words: Seismic design, Earthquake simulation

The chance to couple random-search optimization with procedures to generate earthquake-type functions is outlined. The purpose is to produce simulated earthquakes of the kind that are the most dangerous for the structure under examination, thus contributing to reduce the uncertainty in the calculations.

83-586

The MX Shelter Analysis

J. Isenberg, H.S. Levine, R. Smilowitz, and D.K. Vaughan

Weidlinger Associates, 3000 Sand Hill Rd., Bldg. 4, Suite 245, Menlo Park, CA 94025, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 95-104, Oct 1982, 13 figs, 3 refs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Protective shelters, Missiles, Interaction: soil-structure, Shock tests, Ground shock, Air blast

A one-fifth size generic horizontal shelter was subjected to airblast and ground shock loading in a dynamic air blast simulator. A pretest analysis of soil-structure interaction and and structural response was performed. The scope of the pretest analysis included modeling the airblast; developing cap model parameters for the native soil and backfill cradle; generating a three-dimensional TRANAL soil-structure model using the soil island approach; and generating free-field ground motion input to the soil island model.

83-587

The Use of Structural Response Calculations for Assessing MX Airblast Simulation

J. Isenberg, H.S. Levine, D.K. Vaughan, and E.Q. Richardson

Weidlinger Associates, 3000 Sand Hill Rd., Bldg. 4, Suite 245, Menlo Park, CA 94025, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 105-110, Oct 1982, 5 figs, 4 refs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Protective shelters, Missiles, Air blast, Computer programs, Finite element technique

This paper describes the results of 3-dimensional TRANAL finite element calculations in which a generic MAPS protective horizontal shelter is subjected to airblast from several different explosive simulators. The purpose of the calculations is to evaluate candidate shaped HEST configurations by comparing the effects which the different airblast pressures have on structural response.

83-588

Optimization of Hardened Facility Designs for Nuclear Attack

L.E. Ostermann and J.D. Collins

J.H. Wiggins Co., Redondo Beach, CA 90277, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 111-126, Oct 1982, 13 figs, 5 tables, 4 refs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Protective shelters, Hardened installations, Nuclear weapons effects

A methodology is presented for optimizing shelter designs subjected to nuclear attack. The model accounts for uncertainty in the weapons effects, the responses and the capabilities of the critical components. Using a reference set of design parameters as a basis, these design parameters are adjusted using a nonlinear multivariate optimization technique to maximize survival probability given a specified budget. A cost equation is included to accommodate changes in component costs when the value of the design parameters is changed.

83-589

Analysis of an Explosive Test on Physical Security Devices

W.-W. Shen
Counter Surveillance/Counter Intrusion Lab., U.S. Army Mobility Equipment Res. and Dev. Command, Fort Belvoir, VA 22060, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 45-58, Oct 1982, 13 figs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Explosion effects, Instrumentation response, Measuring instruments

An analysis is given of a special explosive test involving three explosives which were detonated separately in time on the top outside of a magazine. Physical security sensors and transducers were installed on the inner wall of the magazine and the devices included: passive ultrasonic motion sensor, vibration sensor, impact detector, accelerometers, strain sensitive cable and low-frequency microphone. The purpose of the exercise was to test the survivability of these devices under the explosions and to acquire a data base for signature analysis, among other objectives.

VIBRATION EXCITATION

(Also see Nos. 529, 574)

83-590

Excitation of Finite Viscoelastic Solid on Springs

J.M. Fillerup and A.P. Boresi
Mason Hanger Division of Pentex, Amarillo, TX, Nucl. Engrg. Des., 71 (2), pp 179-193 (Aug 1, 1982) 14 figs, 6 refs

Key Words: Viscoelastic media, Springs, Periodic excitation

The objective of this study is to predict the dynamic response of a finite three-dimensional cylindrical standard viscoelastic body supported on the bottom by a spring foundation and subjected to periodic axial force, twist, shear and rocking moment disturbances transmitted through a rigid circular plate bonded concentrically to the top of the body. The results of the analysis may be of use to aid in the proper design of foundations for radar towers, massive reciprocating engines or compressors, vibration and earthquake simulators, etc.

83-591

Analysis of Free and Steady State Vibrations of Nonlinear Structures Using the Finite Element Method

M.A.E. Ghabrial
Ph.D. Thesis, Univ. of Southern California (1982)

Key Words: Nonlinear systems, Free vibration, Periodic response, Finite element technique, Mass-spring systems, Plates, Shells

Two different techniques for dynamic analysis of geometrically nonlinear structures are developed. Applications of the proposed techniques for particular structural configurations are presented. Numerical solutions of each case are compared with those found in the literature.

83-592

Dynamic Response of a Saturated Poroelastic Half-space to Imposed Surface Loadings

M.R. Halpern
Ph.D. Thesis, Carnegie-Mellon Univ., 165 pp (1982) DA8219021

Key Words: Half-space, Porous media, Harmonic excitation

The equivalent of Lamb's problem is reformulated for a liquid-saturated poroelastic halfspace, the objective being to evaluate the response of the solid and fluid phases to harmonic concentrated loads applied to each phase. The poroelastic solutions are evaluated over a broad range of permeabilities and frequencies. A methodology is then introduced by which these results are treated as Green's functions which are used to evaluate the response of the halfspace to the harmonic vertical and rocking motions of rigid pervious and impermeable plates. Halfspace compliances and contact stresses for the solid and fluid are presented.

83-593

Flutter and Vortex Excitation of Rectangular Prisms in Pure Torsion in Smooth and Turbulent Flows

Y. Nakamura and T. Yoshimura
Res. Inst. for Appl. Mech., Kyushu Univ., Fukuoka, Japan, J. Sound Vib., 84 (3), pp 305-317 (Oct 8, 1982) 7 figs, 16 refs

Key Words: Prismatic bodies, Flutter, Torsional vibration, Vortex-induced vibration

Measurements on torsional flutter and vortex excitation of rectangular prisms with depth-to-height ratios ranging from 0·2 to 5·0 were made over a wide range of wind speed in a smooth and in a grid-generated turbulent flow. Particular attention was paid to finding the effect of turbulence on torsional flutter and vortex excitation. It is shown that there are characteristically different effects of turbulence on three types of instability: high speed and low speed torsional flutter and vortex excitation.

83-594

Determination of the Service Life of Lubrication Systems with Rotating Friction Partners Oscillating in Opposition to Each Other (Bestimmung der Lebensdauer von Schmiersystemen mit sich gegeneinander oszillierend drehenden Reibpartnern)

D. Severin and D. Schmidt

VDI Z, 124 (12), pp 447-452 (June 1982) 13 figs, 6 refs

(In German)

Key Words: Lubrication, Friction

The article describes a procedure by which the lubricating conditions in friction pairs with Hertzian contact surfaces and with rotating elements oscillating in opposition to each other can be investigated and by which the service life of such lubricating systems can be determined. Since the test parameters can easily be matched to operating conditions, the results are directly transferable to practice.

83-595

A Self-Phase Modulated Oscillator and Some Implications

B.Z. Kaplan and K. Radparvar

Dept. of Electrical Engrg., Ben-Gurion Univ. of the Negev, P.O. Box 653, Beer Sheva 84120, Israel, J. Franklin Inst., 314 (4), pp 211-217 (1982) 4 figs, 10 refs

Key Words: Oscillators

A self-phase modulated sinewave oscillator is proved to perform as a periodic function generator. The system is investigated comprehensively and is shown to be capable of generating a variety of non-sinusoidal waveforms. The change from the generation of one waveform to the generation of another is attained by the variation of a relatively simple function in a skeletal model which does not change.

83-596

The Three Dimensional Cavity Resonator

G.R. Bigg

Dept. of Appl. Mathematics, Univ. of Adelaide, Adelaide, South Australia 5001, J. Sound Vib., 85 (1), pp 85-103 (Nov 8, 1982) 6 figs, 2 tables, 32 refs

Key Words: Resonators, Helmholtz resonators, Cavity resonators, Matched asymptotic expansion technique

The response of a three dimensional cavity to an external excitation is examined. By using the technique of matched asymptotic expansions the full response curve is predicted, and the low frequency Helmholtz mode is studied in some detail. The results are compared with those of Rayleigh and others to reveal some interesting differences.

83-597

Response of Self-Excited Two-Degree-of-Freedom Systems to Multifrequency Excitations

K.R. Asfar, A.H. Nayfeh, and D.T. Mook

Yarmouk Univ., Irbid, Jordan, J. Sound Vib., 84 (2), pp 199-221 (Sept 22, 1982) 23 figs, 9 refs

Key Words: Two degree of freedom systems, Multifrequency excitation

The response to multifrequency excitation of a two-degree-of-freedom self-excited system is analyzed using the method of multiple scales. Three cases of resonance are considered: superharmonic, primary, and subharmonic. Also considered is the case of simultaneous superharmonic and subharmonic resonance. Steady state and stability analyses carried out for each case and numerical results are presented showing the influences of the several parameters.

83-598

Methods for Minimization of Solution Costs for Transient Dynamic Analysis of Nonlinear Periodic Structures

J.S. Van Kirk, W.T. Bogard, and L.R. Wood

Nuclear Tech. Div., Nuclear Energy Systems, Westinghouse Corp., Pittsburgh, PA 15230, J. Pressure Vessel Tech., Trans. ASME, 104 (3), pp 159-160 (Aug 1982) 2 figs, 4 refs

Key Words: Periodic structures, Nonlinear systems, Transient response

Techniques are described for the transient dynamic analysis of nonlinear periodic structures. These techniques consider the special characteristics of periodic structures in conjunction with the pseudo-force approach using numerical integration to reduce computerized solution costs. Comparisons with a general purpose finite element code demonstrate the savings in solution costs.

equations describing independently cumulative damage in the two cases. Nonlinear interaction between creep and fatigue results from the cumulative rules. The aim of the paper is to remember the essential features of the approach and to apply it to the case of the 304 stainless steel on the basis of experimental data taken from several publications.

MECHANICAL PROPERTIES

DAMPING

(See Nos. 482, 484, 502, 642)

FATIGUE

(Also see No. 656)

83-599

Lifetime Prediction for Metallic Components Subjected to Stochastic Loading

H.H.E. Leipholz, T. Topper, and M. ElMenoufy
Dept. of Civil Engrg., Univ. of Waterloo, Waterloo, Ontario, Canada, N2L 3G1, Computers Struc., 16 (1-4), pp 499-507 (1983) 11 figs, 2 tables, 11 refs

Key Words: Fatigue life, Steel, Stochastic processes

The paper deals with estimating the fatigue life of metallic components of Van-80 steel subjected to stochastic loading of a certain kind. For this loading, the probability of occurrence of events causing damage at well-defined levels can be calculated by means of combinatorics. These probabilities are then used in Miner's rule.

83-600

Lifetime Predictions in 304 Stainless Steel by Damage Approach

G. Cailletaud and J.-L. Chaboche
Office National D'Etudes et de Recherches Aerospatiales, Chatillon, France, ASME Paper No. 82-PVP-72

Key Words: Fatigue (materials), Steel

The proposed method for high temperature lifetime predictions in structures is based on pure creep and pure fatigue

83-601

Creep Fatigue Failure in Austenitic Stainless Steels Relevant to Structural Performance

R. Hales and B. Tomkins
Central Electricity Generating Board, Berkeley, UK, ASME Paper No. 82-PVP-70

Key Words: Fatigue (materials), Steel

Creep fatigue failure in austenitic stainless steels is examined over a wide range of applied strain levels. At low strain levels failure is unlikely to result from a simple creep process where small increments of drainage are accumulated cycle by cycle. At higher strain levels the additional development of fatigue cracks can result in a dramatic reduction in apparent material toughness.

83-602

A Crack Model for Finite Element Analysis of Concrete

H.R. Riggs
Ph.D. Thesis, Univ. of California, 166 pp (1981) DA8212083

Key Words: Reinforced concrete, Cracked media, Cyclic loading, Finite element technique

Although much research has been directed toward developing procedures for the nonlinear analysis of reinforced concrete structures, a general procedure which accounts for all the important phenomena that affect the response has yet to be developed. The objective of the present research has been to increase the analytical capability for reinforced concrete structures subjected to cyclic loading. Specifically, the primary goal has been to model the transfer of shear forces across cracks. Towards this end, an attempt has been made to develop a crack model which is based on the physical mechanisms involved. The basic physics of the model involve a rigid surface sliding over a deformable surface, with friction acting between the surfaces.

83-603
Advances in Computer Aided Design Against Fatigue
C. Musiol, J. Draper, N. Sykes, and K. Morton
British Rail Res. and Dev. Div., Derby, UK, Engineering Research and Design - Bridging the Gap, Instn. Mech. Engrs. Conf. Publ. 1981-7, pp 67-78, C234/81, 8 figs, 3 tables, 9 refs

Key Words: Fatigue life, Computer-aided techniques, Design techniques

A suite of computer programs has been developed which allows advanced fatigue analysis procedures to be incorporated into the overall engineering design process. The programs provide an integrated system of fatigue design and service signal assessment for materials and structural components. Emphasis has been placed on the use of interactive graphics to display intermediate results and enable the non-specialist to gain an understanding of the fatigue processes involved.

83-604
Spall Fracture of Solids
D. Krajcinovic
Mechanics and Metallurgy, Univ. of Illinois at Chicago, Box 4348, Chicago, IL 60680, Shock Vib. Dig. 14 (11), pp 13-17 (Nov 1982) 21 refs

Key Words: Fracture properties, Crack propagation, Reviews

This article contains a summary of general features of material fracture and crack propagation. Analytical methods are reviewed. Passive and active models are described and compared.

83-605
Analysis of Two-Parameter Crack Tip Stress Dynamic Equations in View of Dynamic Photoelasticity
V. Humen, A. Rossler, and B. Stříž
College of Mech. and Textile Engrg., 461 17 Liberec, Czechoslovakia, Strojnícky Časopis, 33 (4), pp 439-455 (1982) 14 figs, 19 refs
(In Czech)

Key Words: Photoelastic analysis, Crack propagation

This paper describes the two-parameter method of analysis for determining the stress intensity factor K from the dynamic photoelastic isochromatic fringe patterns associated with the crack propagating with the constant velocity.

ELASTICITY AND PLASTICITY

83-606
Approximate Techniques for Plastic Deformation of Structures under Impulsive Loading, III
W.E. Baker
Southwest Res. Inst., P.O. Drawer 28510, San Antonio, TX 78284, Shock Vib. Dig., 14 (11), pp 3-11 (Nov 1982) 5 figs, 1 table, 22 refs

Key Words: Impulse response, Plastic deformation, Reviews

Topics of this review on approximate techniques for plastic deformation of structures under loading include research-oriented analyses, design-oriented analyses, and relevant experiments. A brief closure concludes the review; references since 1979 are listed.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

83-607
A Method for Modal Identification of Lightly Damped Structures
D.J. Ewins and P.T. Gleeson
Dept. of Mech. Engrg., Imperial College of Science and Tech., London SW7 2BX, UK, J. Sound Vib., 84 (1), pp 57-79 (Sept 8, 1982) 15 figs, 1 table, 14 refs

Key Words: Undamped structures, System identification techniques, Modal analysis

In many cases model tests are conducted on individual components of complex engineering structures where interest is confined to deriving an undamped model of the structure. A method is proposed for this task which demands a minimum of input data and which, in particular, does not require accurate measurements around resonance. The method is simple to program and its application to various practical structures is described.

83-608
Modal Cross-Spectral Terms May be Important and an Alternative Method of Analysis be Preferable
T. Dahlberg
Div. of Solid Mech., Chalmers Univ. of Tech., S-41296 Gothenburg, Sweden, J. Sound Vib., 84 (4), pp 503-508 (Oct 22, 1982) 2 figs, 6 refs

Key Words: Cross spectral method, Random excitation, Beams, Modal analysis

The influence of modal cross-spectral densities on structural responses is discussed for linear structures excited by narrow band stationary random processes. For a simple beam structure it is shown that these densities play an important role if the narrow band excitation falls close to an anti-resonance of the structure. An alternative formulation of the solution method, in which also modal analysis is used, is given. It is shown that in some cases of interest the alternative formulation yields better accuracy and involves less computational work than the traditional solution method.

83-609
Description of a Coherent Light Technique to Detect the Tangential and Radial Vibrations of an Arch Dam
M. Corti, F. Parmigiani, and S.C.L. Botcherby
CISE S.p.A., 20090 Segrate, Milano, Italy, J. Sound Vib., 84 (1), pp 35-45 (Sept 8, 1982) 12 figs, 1 table, 10 refs

Key Words: Vibration detectors, Vibration measurement, Dams

This paper describes a technique in which a laser light vibration sensor based on a Michelson interferometer is used. With a 5 mW laser the instrument will make measurements on a moving target at ranges greater than 200 m without using retro-reflective materials. Careful optimization of the electro-optic design reduces the effects of environmental disturbances and allows vibration amplitude resolution of 0·2 μm with a flat response in the bandwidth 0·1 – 150 Hz. Field tests and actual measurements of the radial and tangential displacements of an arch dam are shown.

83-610
Directional Acoustic Detection by Resonant Spatial Phase
D.M. Treherne, A. Quinn, S. Jardine, and P.G. Harper
Dept. of Physics, Heriot-Watt Univ., Edinburgh EH14 4AS, UK, J. Sound Vib., 84 (2), pp 191-198 (Sept 22, 1982) 4 figs, 2 tables, 5 refs

Key Words: Resonators, Acoustic resonators, Acoustic excitation

Acoustically induced vibrations in a resonator are studied for their dependence on asymmetric loading imbalance. Both amplitude and spatial phase are measured. Agreement with developed theory suggests a new method for determining acoustic directionality.

83-611
A Spectrum Analyser for Acoustic Emission
I.G. Scott
Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL-MAT-TM-382, 17 pp (June 1982)
AD-A117 720

Key Words: Spectrum analyzers, Acoustic emission

Frequency analysis of acoustic emission (AE) involves the capture and analysis, or real-time analysis, of an impulsive or non-repetitive signal. The present ARL procedure involves the use of a transient recorder and conventional heterodyne spectrum analyzer, and no more than one event per five seconds can be handled. Clark and Mathieson (1977), and Graham (1979), used matched sets of band-pass filters whose center frequencies were related by a fixed ratio. This method of spectral analysis is fast, provides an output suitable for handling by a computer and, by restricting the number of bands, suppresses much unwanted detail in the spectrum. It was chosen for laboratory development and was constructed from available cheap components.

83-612
Fluid Oscillator
A.B. Holmes
Dept. of the Army, Washington, DC, U.S. Patent No. 4 291 395, 6 pp (Sept 22, 1981)

Key Words: Oscillators

A telemetry system is disclosed which utilizes a fluid feedback oscillator in conjunction with a flow restricting device in order to generate pulses in a fluid. Means are provided to turn the oscillator on or off or to vary the frequency of oscillation, thereby permitting the transmission of information by means of the fluid pulses.

83-613

Accelerometers. 1970 - August, 1982 (Citations from the NTIS Data Base)

NTIS, Springfield, VA, 266 pp (Aug 1982)

PB82-873274

Key Words: Accelerometers, Bibliographies

This bibliography contains citations concerning research, design, construction and applications of accelerometers for measurement of motion, vibration, medicine, roughness, waves, shear stress, shock, and gravity.

83-614

Calibration Method for Acoustic Scattering Measurements Using a Spherical Target

L.R. Dragonette

Dept. of the Navy, Washington, DC, Rept. No. PAT-APPL-6-364 098, 21 pp (Mar 1982)

Key Words: Acoustic scattering, Calibrating, Measuring instruments

This abstract discloses a method for calibrating acoustic backscattering instrumentation utilizing a spherical body as a standard target. A spherical body made of high specific acoustic impedance material, such as tungsten carbide, is positioned a given distance from a source/receiver transducer which is energized to produce a short acoustic pulse directed toward the sphere. Acoustic signals reflected from the sphere are detected by the transducer and processed in time domain to separate the rigid portion of the return from the elastic portions. The rigid portion is corrected for the transducer to sphere distance, the reflectivity of the sphere, and for the radius of the sphere. The resultant corrected signal represents the incident acoustic pulse produced by the transducer.

83-615

Sound Intensity – A Powerful New Measurement Tool

R. Upton

Bruel & Kjaer, Naerum, Denmark, S/V, Sound Vib., pp 10, 11-18 (Oct 1982) 21 figs

Key Words: Sound intensity, Measurement techniques, Noise source identification

Traditional sound pressure measurements indicate the total sound pressure level at the receiver. Intensity measurements, on the other hand, can reveal the contributions of individual sources. This article covers some of the background to sound intensity and its applications. Additionally, a new system is described which allows the measurement of sound intensity in real-time.

DYNAMIC TESTS

(Also see No. 589)

83-616

Development of the Freely Expanding Ring Test for Measuring Dynamic Material Properties

R.H. Warnes, R.R. Karpp, T.A. Duffey, A.E. Carden, and J.D. Jacobson

Los Alamos Natl. Lab., NM, Rept. No. LA-UR-82-345, CONF-820516-8, 7 pp (1982)

DE82008122

Key Words: Dynamic tests, Testing techniques

Modifications to the freely expanding ring test for eliminating adverse two-dimensional effects are described and illustrated. The result is to substantially increase the strain-rate range over which dynamic material property data can be reliably obtained. Several different ring launching schemes are discussed, and data are presented that were taken with a particular shockless electromagnetic system. Results from initial attempts at measuring dynamic compressive properties with a contracting ring are presented.

83-617

A Random Vibration Test for the Evaluation of Stiff Sensitive Component Parts

R.W. Nankey

Aircraft Equipment Div., General Electric Co., Utica, NY, J. Environ. Sci., 25 (5), pp 30-33 (Sept/Oct 1982) 5 figs, 19 refs

Key Words: Random vibration, Vibration tests, Testing techniques, Electronic instrumentation, Spacecraft equipment response

A test method is described that can be used to simulate the effects of a high level random vibration environment on a class of component parts. These components are characterized by having their resonant frequencies above the upper frequency limit of the applied vibration spectrum and by being structurally or functionally sensitive to the effects of vibration.

DIAGNOSTICS

83-618
Microchannel-Plate CRT Added to Oscilloscope Speeds Fault Finding
J. Geissinger
Tektronix Inc., Beaverton, OR, Indus. Res. Dev., 24 (11), pp 114-117 (Nov 1982) 4 figs

Key Words: Oscilloscopes, Diagnostic instrumentation

The inability of a standard CRT oscilloscope to detect a fault in an electronic system may be due to the low writing rate of the scope. A new development in the CRT technology is described which uses a microchannel plate to increase the gain in CRT by a factor of 1,000. This enables to see design problems quicker and easier than the usual trial and error method.

83-619
Torsional Vibration Analysis -- Case Histories
H. Schwerdlin
Lovejoy, Inc., 2655 Wisconsin Ave., Downers Grove, IL 60515, Proc. Natl. Conf. on Power Transmission, 9th Annual Mtg., Houston, TX, Nov 16-18, 1982, pp 217-221, 15 figs, 8 refs

Key Words: Diagnostic techniques, Torsional vibration

This paper sets out to present the importance of torsional vibration to those unaware of its causes and effects, and to diagnose premature, torsionally induced failures. By presenting case histories, along with system models and the results of on-site measurements, it is hoped that the importance of this design step is not overlooked.

83-620
A Tribological Study of Ball Skidding in Angular Contact Bearings
G.J. Philips and J.F. Dray
David W. Taylor Naval Ship Res. and Dev. Ctr., Annapolis, MD 21402, Proc. Natl. Conf. on Power Transmission, 9th Annual Mtg., Houston, TX, Nov 16-18, 1982, pp 169-176, 23 figs, 17 refs

Key Words: Diagnostic techniques, Bearings, Ball bearings

An investigation of the tribological performance of duplex angular contact bearings was conducted. Bearing performance was determined experimentally through observations of the bearing speed ratio: the ratio of the outer ball pass frequency to the shaft rotational frequency. Comparisons of experimentally determined values with those developed by bearing analysis computer programs were used to formulate an understanding of the mechanisms that induce ball skidding and noise of such bearings in vertically mounted rotating machinery.

83-621
Instability in a Turbo Generator Rotor
A. Akers
Engrg. Res. Inst. and Dept. of Engrg. Science and Mech., Iowa State Univ., Ames, IA 50011, Proc. Natl. Conf. on Power Transmission, 9th Annual Mtg., Houston, TX, Nov 16-18, 1982, pp 51-57, 4 figs, 1 table, 8 refs

Key Words: Bearings, Turbogenerators, Dynamic stability, Oil whip phenomena

A turbo generator set of 11.5 MW capacity is described which exhibited abnormal oil temperature rise in one of the four journal bearings which support the spindle. In addition to this temperature rise, evidence of oil whip was observed at a power output of approximately 7.5 MW.

ANALYSIS AND DESIGN

ANALOGS AND ANALOG COMPUTATION

(See No. 639)

ANALYTICAL METHODS

(Also see No. 574)

83-622
Periodic System Analysis with Application to Wind Turbines
M. Bahrami

Ph.D. Thesis, Oregon State Univ., 109 pp (1982) DA8224105

Key Words: Turbines, Wind turbines, Turbulence

An algorithm is developed to compute the time averaged, output statistics of a linear system with periodic coefficients forced by stationary white noise. The algorithm makes use of Floquet theory and introduces the averaged system dynamics matrix to obtain more favorable numerical performance. The time series approach to averaged statistics is also examined. Application is made to a wind turbine system with atmospheric turbulence.

83-623

Doubly Asymptotic Approximations as Non-Reflecting Boundaries in Fluid-Structure Interaction Problems

M.S. Soliman

Ph.D. Thesis, Columbia Univ., 45 pp (1982) DA8222490

Key Words: Interaction: structure-fluid, Doubly asymptotic approximation

Acoustic approximations are differential relations between induced pressure and velocity in an acoustic medium. In this paper a procedure is presented for applying the acoustic approximations on a fluid surface which encloses the structure and has a geometry for which virtual mass and fitting matrices have been previously determined. The response may then be obtained by solving numerically the coupled fluid-structure equations in the finite region inside the fluid boundary, which, approximately, is a non-reflecting boundary.

83-624

Simplified Doubly Asymptotic Approximations for Fluid-Structure Interaction

A.S. Kushner and D.E. Ranta

Pacifica Technology, McLean, VA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 52, Supplement 1, pp 1-14 (Oct 1982) 15 figs, 19 refs (52nd Symp. Shock Vib., New Orleans, LA, Oct 26-28, 1981, Spons. SVIC, Naval Res. Lab., Washington, DC)

Key Words: Interaction: structure-fluid, Doubly asymptotic approximation, Plates, Cylinders

Options for reducing the computational complexity of the doubly asymptotic approximation are examined. Two approaches, the PWAM plate approximation and the PWAM cylinder approximation, are proposed. Results from a series of small, two-dimensional test problems are presented.

83-625

Nonlinear Finite Element Formulations for Dynamic Analysis of Mechanisms with Elastic Components

O.I. Sivertsen and A.O. Waløen

Univ. of Trondheim, Norway, ASME Paper No. 82-DET-102

Key Words: Finite element technique, Mechanisms, Component mode synthesis

Large displacement finite element formulations are presented for determining the dynamic response of elastic mechanisms experiencing the nonlinear effects from large rigid-body rotations. Two different approaches are formulated, one direct formulation including all degrees of freedom at primary element level in the solution, and another for reducing the problem size by a superelement technique and the component mode synthesis method.

83-626

The Initial Value Problem for the General Dynamic Equations in Nonlinear Elasticity Theory

H. Beckert

Karl-Marx Universitat, Sektion Mathematik, DDR 7010 Leipzig, Karl Marx-Platz, E. Germany, Z. angew. Math. Mech., 62 (9), pp 357-369 (1982)

Key Words: Boundary value problems

The initial value problem for the general dynamic equations in an elastic continuum is solved. A new form is introduced for these equations and a simple approximation is defined for the solutions of the problem along a difference scheme in the time direction calculating the changing stress configurations.

83-627

Periodic Rayleigh Waves of Finite Amplitude on an Isotropic Solid

N. Kalyanasundaram and G.V. Anand

Dept. of Elec. Communication Engrg., Indian Inst. of Science, Bangalore-560012, India, J. Acoust. Soc. Amer., 72 (5), pp 1518-1523 (Nov 1982) 2 figs, 15 refs

Key Words: Rayleigh waves, Wave propagation, Boundary value problems

Existence of a periodic progressive wave solution to the nonlinear boundary value problem for Rayleigh surface waves of finite amplitude is demonstrated using an extension of the method of strained coordinates. The solution, obtained as a second-order perturbation of the linearized monochromatic Rayleigh wave solution, contains harmonics of all orders of the fundamental frequency. It is shown that the higher harmonic content of the wave increases with amplitude, but the slope of the waveform remains finite so long as the amplitude is less than a critical value.

83-628

On a Variational Theorem in Acousto-Elastodynamics

B.S. Thompson

Dept. of Mech. Engrg., Wayne State Univ., Detroit, MI 48202, J. Sound Vib., 83 (4), pp 461-477 (Aug 22, 1982) 5 figs, 25 refs

Key Words: Variational methods, Equations of motion, Vibrating structures, Acoustic properties, Sound waves

A variational theorem is presented which may be used as a basis for developing the equations of motion and the boundary conditions appropriate for studying the vibrational behavior of flexible bodied systems and the surrounding acoustic medium. The theorem is a generalization of two theorems which are both based on the principle of virtual work; the first governs the elastodynamics of the mechanical system and the second governs the behavior of the fluid medium.

83-629

A New Approach for the Calculation of Response Spectral Density of a Linear Stationary Random Multidegree of Freedom System

A.M. Sharan, S. Sankar, and T.S. Sankar

Dept. of Mech. Engrg., Concordia Univ., Montreal, Canada H3G 1M8, J. Sound Vib., 83 (4), pp 513-519 (Aug 22, 1982) 2 tables, 8 refs

Key Words: Response spectral density, Random vibration

A new approach for the calculation of response spectral density for a linear stationary random multidegree of freedom system is presented. The method is based on modifying the stochastic dynamic equations of the system by using a set of auxiliary variables. The response spectral density matrix obtained by using this new approach contains the spectral densities and the cross-spectral densities of the system generalized displacements and velocities. The new method requires significantly less computation time as compared to the conventional method for calculating response spectral densities. Two numerical examples are presented to compare quantitatively the computation time.

MODELING TECHNIQUES

83-630

The Concave Model for Calculating the Propagation of Noise from Open-Air Industrial Plants

K.J. Marsh

BP Group Engrg. and Technical Ctr., Britannic House, Moor Lane, London EC2Y 9BU, UK, Appl. Acoust., 15 (6), pp 411-428 (Nov 1982) 9 tables, 20 refs

Key Words: Mathematical models, Industrial facilities, Noise generation, Sound propagation

This paper describes a propagation model for calculating neighborhood-noise from open-air industrial plants such as oil refineries and petrochemical plants. It was developed from a preliminary model derived from a comprehensive survey of the literature on noise propagation. The aim was to develop a model which used parameters and procedures available to engineers engaged in plant design.

83-631

Finite Element Simulation for the Acoustical Response of Closed and Open Spaces

M.J. Stanko and A. Seireg

Dept. of Mech. Engrg., Univ. of Wisconsin-Madison, Computers Mech. Engrg., 1 (6), pp 28-34 (Oct 1982) 11 figs, 22 refs

Key Words: Simulation, Finite element technique, Acoustic excitation, Vibrating structures

A structural finite element code is presented for modeling open and closed acoustic spaces subject to a vibrating plate. The code provides an appropriate selection of finite element grid pattern, element size, integration time step, and effective elastic properties for air. Although rigid boundaries and no acoustical damping were considered, the modeling scheme can be readily extended to incorporate natural damping and solid-fluid interaction.

83-632
Calculation of Elastomeric Bearings – Material Theory and the Application of the Finite Element Method (Beitrag zur Berechnung von Elastomerlagern – Materialtheorie und Anwendung der Methode der Finiten Elemente)
C. Schliekmann
Fortschritt-Berichte VDI-Zt., Series 1, No. 91, 102 pp (1982) 93 figs, 2 tables. Summarized in VDI-Z, 124 (20), p 796 (Oct 1982). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany, Price 65.-DM
(In German)

Key Words: Layered materials, Elastomers, Metals, Finite element technique, Approximation methods

Laminates consisting of alternating elastomer-metal layers are used in the construction of bearings of quasi-universal joints for helicopters. In the design of such components current approximation formulas do not take into consideration the effect of metal layers. In this report, a finite element model is presented for a more realistic approximation of the isotropically incompressible or the quasi incompressible behavior of the material.

83-633
A General Procedure for Improving Substructures Representation in Dynamic Synthesis
A.L. Hale and L. Meirovitch
Dept. of Engrg. Science and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061,
J. Sound Vib., 84 (2), pp 269-287 (Sept 22, 1982) 22 refs

Key Words: Substructuring methods, Iteration, Dynamic synthesis

In the general substructure synthesis method for the dynamic analysis of complex flexible structures developed earlier, the motion of each substructure is represented by a given number of substructure admissible functions and the otherwise disjoint substructures are connected together to form a whole structure by imposing approximate geometric compatibility conditions by means of weighted residuals. In this paper, a general procedure for improving the admissible functions representing each substructure in the synthesis is developed. The procedure is an iterative one and it leads to an improved eigensolution for the intermediate structure (i.e., a fictitious structure defined by the approximate compatibility conditions) where the improved eigensolution is obtained while always using the same number of degrees of freedom to represent a given substructure.

NUMERICAL METHODS

83-634
An Eigensolution Strategy for Large Systems
E.L. Wilson and T. Itoh
Dept. of Civil Engrg., Univ. of California, Berkeley, CA 94720,
Computers Struc., 16 (1-4), pp 259-265 (1983) 1 fig, 5 tables, 12 refs

Key Words: Numerical analysis, Natural frequencies, Mode shapes, Iteration

A solution strategy is presented for the evaluation of frequencies and mode shapes for very large structural systems. The subspace iteration method is modified to calculate the eigenpairs in groups near different shift points.

83-635
Exploiting the Limiting Amplitude Principle to Numerically Solve Scattering Problems
G.A. Kriegsmann
Dept. of Engrg. Sciences and Appl. Mathematics, The Technological Inst., Northwestern Univ., Evanston, IL 60201,
Wave Motion, 4 (4), pp 371-380 (Oct 1982) 6 figs, 18 refs

Key Words: Numerical analysis, Wave equation, Wave diffraction

A numerical method for solving reduced wave equations is presented. The technique is basically a relaxation scheme which exploits the limiting amplitude principle. A modified radiation condition at infinity is also given. The method is tested on two model problems: the scattering of plane shallow water waves off shoals and the scattering of plane acoustic waves off a sound-soft cylinder imbedded between two homogeneous but different half spaces. The numerical solutions exhibit correct refractive and diffractive effects at moderate frequencies.

83-636
On Some Unconditionally Stable, Higher Order Methods for the Numerical Solution of the Structural Dynamics Equations
V.A. Dougalis and S.M. Serbin
Mathematics Dept., Univ. of Tennessee, Knoxville,

TN, Intl. J. Numer. Methods Engrg., 18 (11), pp 1613-1621 (Nov 1982) 2 figs, 3 tables, 13 refs

Key Words: Dynamic structural analysis, Numerical analysis

Third- and fourth-order accurate Norsett rational approximations to the exponential and associated semi-implicit Runge-Kutta methods are used for the construction of efficient, accurate and unconditionally stable schemes for the direct numerical integration of the linear, nonhomogeneous, second-order equations of structural dynamics.

STATISTICAL METHODS

83-637

Response of a Multidegree-of-Freedom System of Variable Coefficients to Random Excitation

J. Szopa

Z. angew. Math. Mech., 62 (7), pp 321-328 (July 1982) 17 figs, 11 refs

Key Words: Probability theory, Multidegree of freedom systems, Variable material properties, Random excitation

This paper presents a method of determining probabilistic characteristics concerning the response of a multidegree-of-freedom system with variable coefficients to random excitation. This method is based on the application of a stochastic Volterra integral equation of the second kind and not on the multidegree impulsive response (Green's function) difficult to calculate for this type of system.

83-638

The Exact Steady-State Solution of a Class of Non-Linear Stochastic Systems

T.K. Caughey and F. Ma

California Inst. of Tech., Pasadena, CA 91125, Intl. J. Nonlin. Mech., 17 (3), pp 137-142 (1982) 11 refs

Key Words: Nonlinear systems, Stochastic processes

In this paper exact steady state solutions are constructed for a class of nonlinear systems subjected to stochastic excitation. The results are then applied to both classical and non-classical oscillator problems.

83-639

Analog Computer Simulation of a Duffing Oscillator and Comparison with Statistical Linearization

A.R. Bulsara, K. Lindenberg, and K.E. Shuler

Dept. of Chemistry, Univ. of California, San Diego, La Jolla, CA 92093, Intl. J. Nonlin. Mech., 17 (4), pp 237-253 (1982) 15 figs, 19 refs

Key Words: Analog simulation, Statistical linearization, Oscillators

Results of an analog computer simulation of a Duffing oscillator; i.e., of a damped anharmonic oscillator with a cubic nonlinearity driven by Gaussian white noise, are presented. The simulations were performed for wide ranges of parameter values. The experimentally obtained spectral densities are compared with those obtained analytically using the method of statistical linearization.

83-640

Statistical Theory of Radiative Transfer in Layered Media

G.I. Babkin and V.I. Klyatskin

The Pacific Oceanological Inst., Academy of Sciences of the USSR, Vladivostok, USSR, Wave Motion, 4 (4), pp 327-337 (Oct 1982) 9 figs, 14 refs

Key Words: Wave propagation, Statistical analysis, Layered materials, Random parameters

An equation for probability density of wave intensity, taking into account absorption, is obtained using the invariant imbedding method. The limiting case when the medium occupies a half-space is considered. The field intensity is found for the case of a source inside the medium. The conditions of applicability of the linear theory or radiative transfer are obtained. Numerical solutions of the equations corresponding to the statistical theory of radiative transfer in a layered medium with random inhomogeneities are discussed.

83-641

Experimental Investigation of a Random Repeated Impact Process

L.A. Wood and K.P. Byrne

Engrg. Dept., General Motors -- Holden's Limited, Port Melbourne, Victoria 3207, Australia, J. Sound Vib., 85 (1), pp 53-69 (Nov 8, 1982) 12 figs, 1 table

Key Words: Impact tests, Random excitation, Noise generation, Wheels, Balls, Surface roughness, Probability density function, Normal density functions

A simple random repeated impact process is investigated experimentally. The process, which consists of a ball bouncing on a randomly vibrating surface, is analogous to loss of contact situations which can occur in machinery and transportation systems where a hard rolling element separates from the rolling surface. Experimental data is acquired and processed by using a digital data acquisition system and associated software. Results are obtained in the form of histograms which can be directly compared with the predicted probability density functions.

PARAMETER IDENTIFICATION

83-642
Parameter Identification of a Structure with Combined Coulomb and Hysteretic Damping
M. Rades
Polytechnic Inst., Bucharest, Romania, Rev. Roumaine Sci. Tech., Mecanique Appl., 27 (2), pp 299-308 (Mar/Apr 1982) 6 figs, 12 refs

Key Words: Parameter identification technique, Coulomb friction, Hysteretic damping

A new technique, based on the polar plot analysis of a single degree-of-freedom system with combined Coulomb and hysteretic damping, is presented which allows the system dynamic parameters to be evaluated.

83-643
Structural Parameters Identification in the Frequency Domain for a White Noise Input
M. DiPaola, V.F. Poterasu, and G. Muscolino
Istituto di Scienza delle Costruzioni, Facolta di Ingegneria, Universita di Palermo, Italy, Rev. Roumaine Sci. Tech., Mecanique Appl., 27 (2), pp 237-245 (Mar/Apr 1982) 4 figs, 1 table, 11 refs

Key Words: Parameter identification technique, Frequency domain method, Power spectral density, Fast Fourier transform, Frames

An identification method is given for the determination of the coefficients for a linear vibrating system with many degrees of freedom in the frequency domain. The power spectral density and fast Fourier transform are used, the input of the system being a white noise (Dirac's impulse).

83-644
Improving Analytical Dynamic Models Using Frequency Response Data: Application
G.C. Hart and D.R. Martinez
Sandia Natl. Labs., Albuquerque, NM, Rept. No. SAND-82-0772C, CONF-820527-2, 10 pp (1982) (Pres. at the AIAA/ASME/ASCE/AHS Structures - Structural Dynamics Matls. Conf., New Orleans, LA, May 9, 1982)
DE82008216

Key Words: Parameter identification technique, Frequency response function, Finite elment technique

Results are presented from the successful application of a method to estimate physical parameters of an assumed form parametric (finite element) model. The method employs a form of the iterated extended Kalman filter for parameter estimation with constraints imposed in the form of relative and absolute bounds. Frequency response function data is used as the measurement information.

83-645
ARMA Models for Earthquake Ground Motions
M.K. Chang, J.W. Kwiatkowski, and R.F. Nau
Operations Res. Ctr., Univ. of California, Berkeley, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 10 (5), pp 651-662 (Sept/Oct 1982) 3 figs, 19 refs

Key Words: Earthquake simulation, Parameter identification technique, Ground motion, ARMA (autoregressive/moving-average) models

This paper outlines the use of discrete, autoregressive/moving-average (ARMA) models for identification and estimation of parameters in models derived from analysis of uniformly digitized earthquake ground motion acceleration data. Such models are of equal generality as compared to continuous-time models and have a number of significant advantages for purposes of digital analysis and simulation. The structure of ARMA models is briefly described, their relation to continuous models noted, and results of their application to a number of recorded accelerograms summarized.

83-646

Dynamics of Mass Flow Rate and Pressure in the System Composed of Nonlinear Resistance and Volume

L. Varcop

Res. Inst. of Automation Means, Prague, Czechoslovakia, Strojnicky Casopis, 33 (4), pp 503-511 (1982) 9 figs, 1 ref

(In Czech)

Key Words: System identification techniques, Pneumatic springs

Results of an analytical study of transient phenomena in a system composed of pneumatic resistance and volume are presented. The nonlinear through-flow rate equation of the pneumatic resistance is taken into account.

83-647

Non-Parametric Methods of System Identification

P.E. Wellstead

Control Systems Centre, Inst. of Science and Tech., Univ. of Manchester, UK, Rept. No. CONTROL SYSTEMS CENTRE-496, 57 pp (1982)

PB82-221078

Key Words: System identification techniques, Impulse response, Frequency response

The non-parametric identification of systems in terms of unparametrized representations, such as the impulse response and frequency response, is considered. Basic approaches are outlined in a retrospective setting as are the relationships between non-parametric and parametric identification models. The article concludes with an assessment of non-parametric methods which is conducted in terms of typical industrial applications.

83-648

A Critical Assessment of Deterministic and Statistical Techniques for the Dynamic Identification of Structural Systems Using a Fast Swept Sinusoidal Test Signal

M.J. Lowrey

Inst. of Sound and Vib. Res., Southampton Univ., UK, Rept. No. ISVR-TR-118, 62 pp (Sept 1981)

PB82-253899

Key Words: System identification techniques, Structural members, Beams, Periodic excitation

Test data were obtained for a typical structural component (a 2 m steel beam) subjected to a fast swept sinusoidal excitation, and comparative frequency-domain results obtained using deterministic and statistical procedures. A quantitative comparison of resonant frequencies and damping loss factors was obtained by applying a curve-fitting technique to the complex mobility data.

DESIGN TECHNIQUES

(Also see Nos. 441, 603)

83-649

Suboptimal Controller Design Using Frequency Domain Constraints

R.D. Hefner

Ph.D. Thesis, Univ. of California, 186 pp (1982)

DA8219691

Key Words: Control equipment, Design techniques, Frequency domain method

This dissertation describes a method for designing a controller which is robust with respect to truncated flexible modes. The approach involves minimization of a performance index that combines standard linear regulator penalties with robustness measures in the frequency domain. The frequency domain criteria are chosen so as to sufficiently attenuate the high frequency response of the full dynamic system while maintaining the overall performance of the closed-loop system. Several numerical examples are included to illustrate the features of the approach. The design technique is found to produce stable designs with modest sacrifices in performance.

83-650

Second-Order Design Sensitivity Analysis of Mechanical System Dynamics

E.J. Haug and P.E. Ehle

Univ. of Iowa, Iowa City, IA, Intl. J. Numer. Methods Engrg., 18 (11), pp 1699-1717 (Nov 1982) 7 figs, 1 table, 5 refs

Key Words: Structural modification effects, Design techniques, Dynamic response, Mechanical systems

Dependence of dynamic response of nonlinear mechanical systems on design variables is analyzed. An adjoint variable method is used to derive first- and second-order derivatives of measures of dynamic response with respect to design variables. A computational algorithm is presented for numerical calculation of first and second design derivatives. A simple oscillator example is solved analytically and by the adjoint variable method, with identical results.

83-651

Producing Stress and Vibration Analysis Data for Engineering Design

T.H. Richards

Dept. of Mech. Engrg., The Univ. of Aston in Birmingham, UK, Engineering Research and Design -- Bridging the Gap, Instn. Mech. Engrs. Conf. Publ. 1981-7, pp 59-66, C233/81, 5 figs, 1 table

Key Words: Vibration analysis, Computer-aided techniques, Design techniques, Rayleigh-Ritz method

Factors influencing the effective transfer of new and nearly new research information into low/intermediate technology fields are discussed. It is suggested that the microcomputer is a most effective vehicle for this purpose, providing a new lease of life to established information to be incorporated in tailor made CAD packages. Some examples are described which illustrate that the Rayleigh-Ritz technique still has a useful role to play in mechanical analysis even in these days of finite elements.

COMPUTER PROGRAMS

83-652

Dynamic Structural Analyses of a Spacecraft Using Experimental Modal Data

A. Bertram and P. Conrad

Deutsche Forschungs- und Versuchsanstalt fuer Luft und Raumfahrt e.V., Goettingen, Fed. Rep. Germany, Rept. No. DFVLR-IB-232-81-C-06, ESA-CR(P)-1510, 96 pp (May 12, 1981)

N82-25317

Key Words: Computer programs, Spacecraft, Modal analysis

Application of software for modal coupling and configuration change calculation to a complicated modular spacecraft structure with typical interface connections and appendages using data from structures already tested experimentally is summarized. Criteria for selecting the most suitable mode sets for modal synthesis are established.

83-653

An Interactive Force System Synthesis Program for Use with a Host Mechanism Dynamic Analysis Program

W.L. Carson and C.E. Lee

Univ. of Missouri-Columbia, Columbia, MO, ASME Paper No. 82-DET-74

Key Words: Computer programs, Mechanisms

An interactive computer program is described for structurally and dimensionally synthesizing force systems to drive a mechanism to have a desired motion time response and input-output forces. The program can be used for any planar one-degree-of-freedom linkage. A mechanism dynamic analysis program is used as a host to generate pre- and post-synthesis data.

83-654

Vehicle Dynamics and Crash Dynamics with Minicomputer

V. Giavotto, L. Puccinelli, and M. Borri

Program Development and Tech. Appliance Ltd. SPAT, Alberata 401, Milano 2 Segrate, Italy, Computers Struc., 16 (1-4), pp 381-393 (1983) 18 figs, 10 refs

Key Words: Computer programs, Collision research (automotive)

This paper concerns the definition and the development of the VEDYAC system, which is a general purpose software for the simulation of the dynamics of road accidents. The paper describes the main features of the VEDYAC project and shows the results of significant simulations, with some evaluations and comparisons with experimental results.

83-655

Subsonic Aerodynamic and Flutter Characteristics of Several Wings Calculated by the SOUSSA P1.1 Panel Method

E.C. Yates, Jr., H.J. Cunningham, R.N. Desmarais, W.A. Silva, and B. Drobenko

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-84485, 21 pp (May 1982) (Pres. at the AIAA/ASME/ASCE/AHS 23rd Structures, Structural

Dynamics Matls. Conf., New Orleans, May 10-12, 1982)
N82-25216

Key Words: Computer programs, Aircraft wings, Flutter

The SOUSSA (steady, oscillatory, and unsteady subsonic and supersonic aerodynamics) program is the computational implementation of a general potential flow analysis (by the Green's function method) that can generate pressure distributions on complete aircraft having arbitrary shapes, motions and deformations. Some applications of the initial release version of this program to several wings in steady and oscillatory motion, including flutter are presented.

83-656

A FORTRAN Program for Calculating Three Dimensional, Inviscid and Rotational Flows with Shock Waves in Axial Compressor Blade Rows: User's Manual

W.T. Thompkins, Jr.
Gas Turbine and Plasma Dynamics Lab., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. NASA-CR-3560, 179 pp (June 1982)
N82-26230

Key Words: Computer programs, Compressor blades, Blades, Rotors, Shock waves

A FORTRAN-IV computer program was developed for the calculation of the inviscid transonic/supersonic flow field in a fully three dimensional blade passage of an axial compressor rotor or stator. Rotors may have dampers (part span shrouds). MacCormack's explicit time marching method is used to solve the unsteady Euler equations on a finite difference mesh. This technique captures shocks and smears them over several grid points. Input quantities are blade row geometry, operating conditions and thermodynamic quantities. Output quantities are three velocity components, density and internal energy at each mesh point. Other flow quantities are calculated from these variables.

83-657

STEUL: Computer Program for Air Shock Wave Loaded Euler Girders (STEUL: Datormodell Foer Luftstoetvaagsbelastad Eulerbalk)

I. Aaseborn and J.E. Jonasson
Foersvarets Forskningsanstalt, Stockholm, Sweden, Rept. No. FOA-C-20440-D4(A3), 59 pp (Jan 1982)
N82-25549
(In Swedish)

Key Words: Girders, Shock excitation, Bernoulli-Euler method, Computer programs

The analytic solution for dynamically loaded girders (Bernoulli-Euler theory) is developed and a computer program is presented. Bending moment and shear stress distributions are expressed as time functions. The variable load consists of an overpressure phase followed by an underpressure phase for three typical conditions: simply supported girders, or maximum rigidity at one or at both supports.

83-658

Automated Stress Analysis of Mechanical Sheaves and Pulleys

M. Saraph, A. Midha, and J.C. Wambold
Dept. of Engrg., Science and Mech., Pennsylvania State Univ., University Park, PA, Computers Mech. Engrg., 1 (6), pp 35-42 (Oct 1982) 10 figs, 1 table, 10 refs

Key Words: Computer programs, Design techniques, Stress analysis, Power transmission systems, Pulleys, Three-dimensional problems

A general-purpose program, SAPIV, is described which can perform static and dynamic analyses of large 3-D problems and show the effects of varying design parameters.

83-659

On the Use of APES and BIGIF Programs in the Fracture Mechanics, Thermal Stress, and Fatigue Analyses of Gas Turbine Components

K. Arin
General Electric Co., Schenectady, NY, ASME Paper No. 82-GT-324

Key Words: Computer programs, Shafts, Gas turbines, Fracture properties, Fatigue life

The use of two computer programs, APES and BIGIF, which utilize the finite element and the boundary integral equation methods of analysis, respectively, is discussed, and their application to problems associated with gas turbine components is demonstrated.

83-660

Engine Dynamic Analysis with General Nonlinear Finite-Element Codes, Part 1: Overall Approach and Development of Bearing Damper Element

M.L. Adams, J. Padovan, and D.G. Fertis

Univ. of Akron, Akron, OH 44325, J. Engrg. Power, Trans. ASME, 104 (3), pp 586-593 (July 1982) 13 figs, 12 refs

Key Words: Computer programs, Finite element technique, Squeeze-film bearings, Squeeze-film dampers, Aircraft engines, Turbine engines

There is currently a considerable interest and level of activity in developing computational schemes to predict general engine dynamic behavior. Proper account of system nonlinearities (particularly at the bearings, dampers and rubs) appears to be necessary if analytical predictions are to be realistic. The approach described in this paper seeks to make use of already proven general finite-element nonlinear time-transient computer codes which are available on the open market. The work specifically described in this paper covers the first phase of a three-phase NASA-Lewis-sponsored research grant on engine dynamic simulation with available finite element codes.

83-661

MAGNA: A Finite Element Program for the Materially and Geometrically Nonlinear Analysis of Three-Dimensional Structures Subjected to Static and Transient Loading

R.A. Brockman

Research Inst., Dayton Univ., OH, Rept. Nc UDR-TR-81-148, AFWAL-TR-81-3181, 624 pp (Feb 1982)

AD-A116 541

Key Words: Computer programs, Finite element technique, Nonlinear theories

The finite element program MAGNA (materially and geometrically nonlinear analysis), developed for the nonlinear static and dynamic analysis of complex three-dimensional structures, is described. This program is applicable to large structural response problems involving bars, membranes, plates, shells, and axisymmetric and three-dimensional solids, experiencing large displacements, finite strains, large rotations and plastic deformation. The theoretical basis of MAGNA and the numerical procedures employed are described in detail.

GENERAL TOPICS

TUTORIALS AND REVIEWS

(See Nos. 480, 606)

BIBLIOGRAPHIES

(Also see No. 613)

83-662

Vibrational Analysis in Fluids. 1972 - August, 1982 (Citations from the International Aerospace Abstracts Data Base)

NTIS, Springfield, VA, 123 pp (Aug 1982)

PB82-873134

Key Words: Bibliographies, Fluids, Vibration analysis

This bibliography contains citations concerning analyses of vibrational, fatigue, stress, and mechanical responses of fluid systems through a range of applications. Experimental studies relative to various shapes and mechanisms working within fluid systems applicable to numerous fields are examined. Specific data and procedures include applications in structural mechanics, aerodynamics, hydrodynamics, and hydraulics.

AUTHOR INDEX

Aaseborn, I. 657
Abounassif, J.. 509
Abuelnaga, A.. 458
Adali, S. 527
Adamczyk, J.J.. 491
Adams, M.L.. 660
Ahuja, K.K. 463
Akers, A.. 621
Albrecht, P.R.. 505
Allison, I.M.. 441
Anand, G.V.. 627
Ando, T. 555
Andries, G.C. 435
Aoki, T.. 583
Arin, K.. 659
Asfar, K.R.. 597
Atkins, K.J. 512
Baber, B.B.. 500
Babkin, G.I. 640
Baggi, C. 509
Bahrami, M. 622
Baker, W.E. 606
Ball, J.W.. 437
Balsara, J.P. 437
Bandyopadhyay, S.S.. 444
Baratta, A.. 585
Baron, M.L. 471
Barton, J.R.. 500
Basavanhally, N. 523
Beckert, H.. 626
Beltzer, A.I. 575
Benda, L.. 464
Bendiksen, O.O. 490
Bernhardt, U. 566
Berry, R.L.. 475
Bert, C.W. 530
Bertram, A. 652
Bigg, G.R. 596
Blume, J.A. 549
Bogard, W.T. 598
Bogdonoff, S.M. 582
Boresi, A.P. 590
Borri, M. 654
Botcherby, S.C.L. 609
Bowsher, J.M.. 570
Brand, R.S. 557, 571
Brannen, W.F.. 517
Brockman, R.A. 661
Buchheim, R 459
Bulsara, A.R 639
Butler, D.. 541
Button, M.R. 439
Byrne, K.P. 641
Cailletaud, G. 600
Calladine, C.R. 515
Card, M.F. 481
Carden, A.E.. 616
Carson, W.L.. 653
Caughey, T.K.. 638
Chaboche, J.-L.. 600
Chang, M.K.. 645
Chang, M.T. 568
Chao, T.S. 535
Chaudhuri, S.K. 539
Childs, D.W.. 430
Chonan, S.. 516
Chou, C.K.. 450
Chwang, A.T. 442
Clements, D.L. 537
Collins, J.D. 588
Conrad, P. 652
Constantinou, M.C. 510
Cooke, D.W.. 521
Cookson, R.A. 502
Cornell, C.A. 446
Corti, M. 609
Crespo, E. 439
Crespo Da Silva, M.R.M. 528
Culick, F.E.C.. 556
Cummings, G.E. 449
Cunningham, H.J. 655
Dahlberg, T. 608
Davies, H.G.. 522
Desmarais, R.N. 655
DeWoody, R.T.. 477
Dietrich, W. 436
DiMaggio, F.L. 471
Dimarogonas, A. 506
DiPaola, M. 643
Dobrzynski, W. 459
Dolling, D.S.. 582
Donikian, R.. 439
Dougalis, V.A. 636
Dow, T.A. 494
Dragonette, L.R.. 614
Draper, J.. 603
Dray, J.F. 620
Driels, M.R. 577
Drobenko, B. 655
Duffey, T.A.. . . . . .455, 616
Dunn, M.G. 578
Dyckes, G.W. 581
Eastep, F.E. 531
Eatwell, G.P. 541
Ehle, P.E.. 650
Eisler, T. 529
ElMenoufy, M. 599
Elton, R.W. 467
Erskine, J.B.. 569
Eshleman, R.L.. 508
Ewins, D.J.. 607
Farkas, J.. 526
Ferenczi, M.. 460
Fertis, D.G. 660
Fillerup, J.M. 590
Freedman, A. 532
Friedmann, P.P. 490
Fry, M. 579
Gallus, H.E. 489
Gartner, J.R. 524
Geissinger, J. 618
Ghabrial, M.A.E.. 591
Giavotto, V.. 654
Gibby, J.A. 525
Gilbert, C. 483
Gleeson, P.T. 607
Green, G.M.. 461
Grollius, H. 489
Gubser, J.L.. 467
Gunter, E.J.. . . . . .431, 432
Guntur, R.R. 484
Gupta, S.. 549
Hagler, R.J. 507
Hajek, J.J. 572
Hale, A.L. 633

Hales, R. 601
Hallauer, W.L., Jr. 520
Halpern, M.R.. 592
Hamdi, M.A.. 558
Harper, P.G. 610
Hart, G.C. 644
Hashimoto, H. 501
Haug, E.J. 650
Hayashi, N. 534
Hefner, R.D.. 649
Hemmig, F.G.. 531
Herbert, J.T.. 457
Hill, D. 537
Hinchey, M.J.. 461
Hodson, K.E. 438
Hoffman, B.W. 507
Hofr, J. 464
Holmes, A.B. 612
Holmes, P.J.. 542
Honma, T. 451
Hubbard, H.H. 440
Hughes, G. 519
Humen, V. 605
Hundal, M.S. 486
Hunt, J.B. 474
Ida, H.. 538
Iguchi, M. 554
Ikui, T. 583
Ikushima, T. 451, 452
Imai, K.. 453
Inaba, A. 476
Irie, T.. 538
Isenberg, J.. . . . . .586, 587
Ishizuka, H. 451
Itoh, T. 634
Jacobson, J.D. 616
James, J.H.. 547
Jardine, S. 610
Jarmai, K. 526
Jaskie, J.E.. 478
Jefferys, E.R. 456
Jenkins, J.E.. 468
Jha, V.K.. 469
Jhaveri, D.P.. 549
Jonasson, J.E.. 657
Jutras, R.. 491
Kadle, D.S.. 442
Kalyanasundaram, N. 627
Kamman, J.W. 513
Kanada, S. 473
Kannel, J.W.. 494
Kaplan, B.Z.. 595
Karpp, R.R. 455, 616
Kelly, T.E. 439
Khandoker, S.I.. 522
Kitis, L.. 480
Klyatskin, V.I. 640
Kobari, T. 516
Kobayashi, F. 473
Kohler, A. 503
Kohli, D. 478
Kondoh, N. 583
Konno, M. 540
Kosawada, T. 540
Kossa, S.S. 502
Koyoyannakis, D. 553
Krajcinovic, D. 604
Krawinkler, H. 563
Kriegsmann, G.A. 635
Kulkarni, S.V.. 493
Kurata, M. 482
Kusenberger, F.N. 500
Kushner, A.S. 624
Kustu, O.. 549
Kuttruff, H. 567
Kwiatkowski, J.W.. 645
Lambertz, J.. 489
Laskin, R.A.. 470
Lee, C.E. 653
Leipholz, H.H.E. 599
LeKuch, H. 483
Lemke, M. 443
Lever, J.H.. 552
Levine, H.S. 586, 587
Levinson, M.. 521
Li, D.F. 431, 432
Li, Y.-C. 462
Lin, C.F. 466
Lindenberg, K. 639
Liu, R.Y.L. 520
Liu, Y.Y. 525
Loewenthal, S.H.. 499
Lotfy, A.A. 533
Lowrey, M.J. 648
Ma, F. 638
Maidanik, G.. 529
Majerus, J.N. 536
Mallik, A.K. 546
Mankau, H. 459
Marangoni, R.D. 523
Markho, P.H. 497
Marsh, K.J.. 630
Marshek, K.M. 435
Martinez, D.R. 644
Matsuo, K. 583
Mayes, R.L. 439
Mazumdar, J. 537
McComb, H.G., Jr.. 481
McCormick, J. 471
Meirovitch, L.. 633
Meyer, C.. 471
Meyer, J. 436
Michalopoulos, D. 506
Michelberger, P. 460
Midha, A.. 658
Minami, M.. 453
Miyajima, M. 476
Mizutani, K. 434
Moayyad, P. 584
Mook, D.T. 597
Moon, J. 564
Morita, M. 543
Morton, K.. 603
Moyer, D.W.. 499
Muramatsu, T. 473
Muscolino, G. 643
Musiol, C. 603
Mussaini, M.Y. 580
Nagaraj, V.T. 492
Nagel, R.T.. . . . . .557, 571
Nahm, A.H. 495
Naji, M.R. 435
Nakagawa, T. 473
Nakamura, Y. 593
Nankey, R.W. 617
Nau, R.F.. 645
Nayfeh, A.H. 597
Neal, T.R. 455
Needelman, W.M. 499
Nissen, J.-C. 474
Nomoto, H. 556
Nypan, L.J. 498
Ohmi, M. 554
Ohrstrom, E. 472
Ohta, M. 453
Okada, Y. 482
Oldham, D.J. 561
Olgac, N. 524
Ono, S. 453
Ortloff, J.E. 457
Ostermann, L.E. 588
Ota, H. 434
Padovan, J.. 660

Paidoussis, M.P. 544, 545
Parmigiani, F. 609
Patel, M.H 456
Peat, K.S. 559
Peebles, S.W. 481
Peeken, H. 503
Philips, G.J. 620
Pilkey, W.D. 480
Pillasch, D.W. 536
Pinkus, O. 504, 505
Planchard, J. 551
Plotkin, K.J. 487, 488
Poterasu, V.F. 643
Price, S.J. 544, 545
Puccinelli, L. 654
Quinn, A. 610
Racca, R., Sr. 479
Rades, M. 642
Radparvar, K. 595
Rafferty, J.M. 578
Ramakrishnan, R. 463
Ramamurthy, S. 454
Ranta, D.E. 624
Rao, J.S. 493
Reddy, E.S. 546
Remy, F.N. 551
Richards, T.H. 651
Richardson, E.Q. 587
Riera, J.D. 445, 447
Riggs, H.R. 602
Rosener, A.A. 485
Rossler, A. 605
Rylander, R. 472
Saiidi, M. 438
Saito. H. 516
Salas, M.D. 580
Salikuddin, M. 463
Salje, E. 436
Sandler, I. 471
Sankar, S. 484, 629
Sankar, T.S. 629
Saraph, M. 658
Sawada, T. 555
Scherer, R.J. 447
Schliekmann, C. 632
Schmidt, D. 594
Schüller, G.I. 445, 447
Schwabe, D. 459
Schwerdlin, H. 508, 619
Scott, I.G. 611
Seebold, J.G. 548
Seireg, A. 458, 631
Serbin, S.M. 636
Severin, D. 594
Sewell, E.C. 562
Shah, M.J. 454
Sharan, A.M. 629
Shen, W.-W. 589
Shen, Y. 561
Shimizu, M. 453
Shirakawa, K. 543
Shuler, K.E. 639
Silva, W.A. 655
Simonyi, A. 460
Sivertsen, O.I. 625
Smilowitz, R. 586
Smith, P.D. 448
Sol, J.C. 433
Soliman, M.S. 623
Sonneville, P. 551
Speirs, D.M. 519
Stalker, R.J. 465
Stanko, M.J. 631
Stevans, W. 491
Stříž, B. 605
Stusnick, E. 487, 488
Subrahmanyam, K.B. 493
Suen, H.-C. 544, 545
Sulc, J. 464
Sullivan, P.A. 461
Sung, C.K. 511
Suzuki, K. 540
Swinerd, G.G. 532
Sykes, N. 603
Szopa, J. 637
Tadjbakhsh, I.G. 510
Takahashi, S. 540
Takatsu, H. 453
Tallian, T.E. 496
Tanahashi, M. 473
Tanahashi, T. 555
Taylor, J.S.W. 441
Thompkins, W.T., Jr. 656
Thompson, B.S. 511, 628
Thompson, J.D. 455
Thompson, J.K. 565
To, C.W.S. 518, 574
Tomkins, B. 601
Topper, T. 599
Treherne, D.M. 610
Tsai, M.S. 560
Ukeje, E. 576
Upton, R. 615
Vaičaitis, R. 568
Van Kirk, J.S. 598
Varcop, L. 646
Vaughan, D.K. 586, 587
Venkatesan, C. 492
Ville, J.M. 558
Vinh, N.X. 466
Visser, A.T. 573
Vukelich, S.R. 468
Wada, S. 501
Wagner, W. 550
Walker, R.N. 573
Walpen, A.O. 625
Walowit, J. 504, 505
Wambold, J.C. 658
Wang, B.P. 480
Wang, J.T.S. 525
Wang, T.M. 517
Warnes, R.H 455, 616
Watkinson, P.S. 570
Weaver, D.S. 552, 553
Wellstead, P.E. 647
Willumeit, H.-P. 443
Wilson, E.L. 634
Wood, L.A. 641
Wood, L.R. 598
Yamada, G. 538
Yamada, S. 473
Yamanaka, K. 473
Yamashita, Y. 555
Yang, H.J. 482
Yankov, Y.I. 514
Yasuda, K. 534
Yates, E.C., Jr. 655
Yong, K.H. 512
Yoshimura, T. 593
Zak, A.R. 536
Zang, T.A. 580
Zara, J.A. 467
Zohrei, M. 563
Zorn, N.F. 445

TECHNICAL NOTES

K.K. Raju and G.V. Rao
A Note on the Choice of Constraint Values on the Non-Dimensional Frequency Parameter in Optimization Problems
J. Sound Vib., 83 (2), pp 299-300 (July 22, 1982) 1 table, 2 refs

K.K. Ahuja and C.K.W. Tam
A Note on the Coupling between Flow Instabilities and Incident Sound
J. Sound Vib., 83 (3), pp 433-439 (Aug 8, 1982) 3 figs, 18 refs

W.P. Rodden and E.D. Bellinger
Unrestrained Aeroelastic Divergence in a Dynamic Stability Analysis
J. Aircraft, 19 (9), pp 796-797 (Sept 1982) 2 figs, 14 refs

B.Z. Kaplan and K. Radparvar
Canonic Coupling of Sinusoidal Oscillators
IEEE, Proc., 70 (9), pp 1130-1132 (Sept 1982) 7 refs

D.W. Barnette
Dynamic Elastic Analysis of a Seabed Cover
AIAA J., 20 (11), pp 1622-1623 (Nov 1982) 2 figs, 1 table, 4 refs

M.W. Huggins and J.D. Barber
Building Deflections, Distortions, and Vibrations -- A Survey
Can. J. Civ. Engrg., 9 (1), pp 133-140 (Mar 1982) 3 figs, 2 tables

H.E. von Gierke, D.W. Robinson, and S.J. Karmy
Results of a Workshop on Impulse Noise and Auditory Hazard
J. Sound Vib., 83 (4), pp 579-584 (Aug 22, 1982) 13 refs

N.G. Stephen
Note on the Combined Use of Dunkerley's and Southwell's Methods
J. Sound Vib., 83 (4), pp 585-587 (Aug 22, 1982) 1 table, 2 refs

G. Deri
Calculation of the Natural Frequencies of a Flexurally Vibrating Beam of Constant Cross Section Supported Elastically at Both Ends and Loaded in the Middle by a Concentrated Mass (Berechnung der Grundfrequenz des beiderseits gelenkig gelagerten, biegeschwingenden Stabes mit konstantem Querschnitt, in der Mitte mit einer konzentrierten Masse belastet)
Z. angew. Math. Mech., 62 (9), pp 408-409 (1982) (In German)

H.R. Srirangarajan
Oscillator with Weak Non-Linear Damping
J. Sound Vib., 84 (1), pp 153-155 (Sept 8, 1982) 3 refs

T. Merriman and R. Singh
Modal Analysis of a Human Head Impact Simulator
J. Sound Vib., 84 (1), pp 156-159 (Sept 8, 1982) 2 figs, 1 table, 9 refs

N.W.M. Ko
Effects of a 45° Sharp Edge on an Excited Jet
J. Sound Vib., 84 (1), pp 149-152 (Sept 8, 1982) 4 figs, 3 refs

Y. Sugiyama, T. Iwatsubo, and K. Ishihara
Parametric Resonances of a Cantilevered Column under a Periodic Tangential Force
J. Sound Vib., 84 (2), pp 301-303 (Sept 22, 1982) 2 figs, 3 refs

J. Mathew and R.J. Alfredson
An Improved Model for Predicting the Reflection of Acoustical Transients from Fibrous Absorptive Surfaces
J. Sound Vib., 84 (2), pp 296-300 (Sept 22, 1982) 3 figs, 5 refs

D.G. Simmonds
The Response of a Simple Pendulum with Newtonian Damping
J. Sound Vib., 84 (3), pp 453-461 (Oct 8, 1982) 6 figs, 3 tables, 2 refs

CALENDAR

APRIL 1983

18-20 Materials Conference [ASME] Albany, NY *(ASME Hqs.)*

18-21 Institute of Environmental Sciences' 29th Annual Technical Meeting [IES] Los Angeles, CA *(IES, 940 E. Northwest Highway, Mount Prospect, IL 60056 - (312) 255-1561)*

19-21 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Houston, TX *(Ronald L. Eshleman, Director, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)*

21-22 14th Annual Modeling and Simulation Conference [Univ. of Pittsburgh] Pittsburgh, PA *(William G. Vogt, Modeling and Simulation Conf., 348 Benedum Engineering Hall, Univ. of Pittsburgh, Pittsburgh, PA 15261)*

MAY 1983

9-13 Acoustical Society of America, Spring Meeting [ASA] Cincinnati, OH *(ASA Hqs.)*

9-13 Symposium on Interaction of Non-Nuclear Munitions with Structures [U.S. Air Force] Colorado Springs, CO *(Dr. C.A. Ross, P.O. Box 1918, Eglin AFB, FL 32542 - (904) 822-5614)*

17-19 Fifth Metal Matrix Composites Technology Conference [Office of the Undersecretary of Defense for Research and Engineering] Naval Surface Weapons Center, Silver Spring, MD *(MMCIAC - Kaman Tempo, P.O. Drawer QQ, Santa Barbara, CA 93102 - (805) 963-6455/6497)*

JUNE 1983

6-10 Passenger Car Meeting [SAE] Dearborn, MI *(SAE Hqs.)*

20-22 Applied Mechanics, Bioengineering & Fluids Engineering Conference [ASME] Houston, TX *(ASME Hqs.)*

JULY 1983

11-13 13th Intersociety Conference on Environmental Systems [SAE] San Francisco, CA *(SAE Hqs.)*

AUGUST 1983

8-11 Computer Engineering Conferences and Exhibit [ASME] Chicago, IL *(ASME Hqs.)*

8-11 West Coast International Meeting [SAE] Vancouver, B.C. *(SAE Hqs.)*

SEPTEMBER 1983

11-13 Petroleum Workshop and Conference [ASME] Tulsa, OK *(ASME Hqs.)*

11-14 Design Engineering Technical Conference [ASME] Dearborn, MI *(ASME Hqs.)*

12-15 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI *(SAE Hqs.)*

14-16 International Symposium on Structural Crashworthiness [University of Liverpool] Liverpool, UK *(Prof. Norman Jones, Dept. of Mech. Engrg., The Univ. of Liverpool, P.O. Box 147, Liverpool L69 3BX, England)*

25-29 Power Generation Conference [ASME] Indianapolis, IN *(ASME Hqs.)*

OCTOBER 1983

17-19 Stapp Car Crash Conference [SAE] San Diego, CA *(SAE Hqs.)*

17-20 Lubrication Conference [ASME] Hartford, CT *(ASME Hqs.)*

18-20 54th Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, DC] Pasadena, CA *(Mr. Henry C. Pusey, Director, SVIC, Naval Research Lab., Code 5804, Washington, DC 20375)*

NOVEMBER 1983

6-10 Truck Meeting and Exposition [SAE] Cleveland, OH *(SAE Hqs.)*

7-11 Acoustical Society of America, Fall Meeting [ASA] San Diego, CA *(ASA Hqs.)*

13-18 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Boston, MA *(ASME Hqs.)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
Owles Hall, Buntingford, Herts.
SG9 9PL, England

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - U.S. National Committee
c/o MIT Lincoln Lab.
Lexington, MA 02173

*U.S. GOVERNMENT PRINTING OFFICE : 1983 0-381-334/603

PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined
- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, number or issue, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addision-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).
4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).
5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 1500 to 2500 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tamulionis
Research Editor
Vibration Institute
101 W. 55th Street, Suite 206
Clarendon Hills, Illinois 60514

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY, CODE 5804
SHOCK AND VIBRATION INFORMATION CENTER
Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD-316

U.S.MAIL ®

THIRD CLASS MAIL

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA, VA 22314

THE SHOCK AND VIBRATION DIGEST

Volume 15, No. 3 **March 1983**

EDITORIAL

1 SVIC Notes
2 Editors Rattle Space

ARTICLES AND REVIEWS

3 Feature Article - FINITE DIFFERENCE METHODS IN VIBRATION ANALYSIS
R. Ali

8 Literature Review

9 DYNAMIC APPLICATIONS OF PIEZOELECTRIC CRYSTALS. PART I: FUNDAMENTALS
M.C. Dökmeci

21 DIGITAL SYNTHESIS OF RESPONSE-DESIGN SPECTRUM COMPATIBLE EARTHQUAKE RECORDS FOR DYNAMIC ANALYSES
P-T.D. Spanos

31 Book Reviews

CURRENT NEWS

36 Short Courses
39 Previews of Meetings

ABSTRACTS FROM THE CURRENT LITERATURE

41 Abstract Categories
42 Abstract Contents
43 Abstracts: 83-430 to 83-662
94 Author Index
97 Technical Notes

CALENDAR